# SCIENTIFIC AMERICAN SUPPLEMENT. No. 1568

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Scientific American, established 1845.
Scientific American Supplement, Vol. LXI., No. 1568

NEW YORK, JANUARY 20, 1906.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.


## THE RHODESIA RAILWAYS IN SOUTH AFRICA.*

By FRANK C. PERKINS.

THE construction of railways in South Africa has been of the greatest importance in the development of the country, the same as in every other newly-settled land, particularly as there are absolutely no navigable streams, and the great expense of building roads on the vast sandy tracts of land has made the railways of still greatef value than in other newly-developed countries.

In 1903 the Bulawayo-Zambesi line was placed in operation to Wankie coal-field from Cape Town, a distance of 1,572 miles. At this point there is an abundance of coal, which is necessary in railway operations. During the past year the construction was carried on to Victoria Falls, 1,640 miles from Cape Town. It is stated that the rails are now laid a hundred miles or more beyond Zambesi and several hundred miles into the interior, completing two thousand miles of unbroken railway lines in the great "Cape to Cairo" construction.

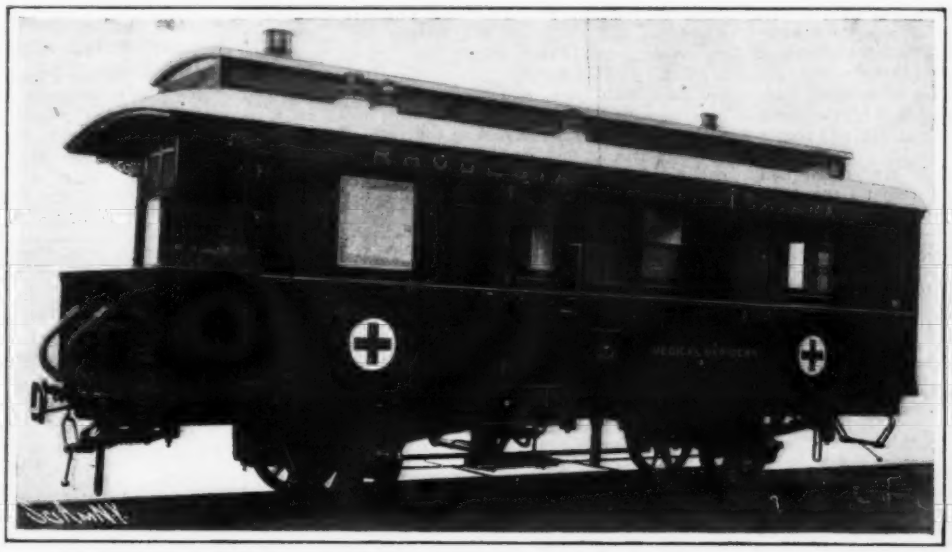
It is said that the railway from Bulawayo to Mafeking is operated by the Cape government railways, and those north of Bulawayo are run by the Beira and Mashonaland railways. The accompanying illustrations show the type of cars used on the Rhodesia railways in South Africa, and an interesting type of locomotive constructed in England for the Rhodesia lines by Kitson & Co., Ltd., of Leeds. The cab is especially large and roomy, for the comfort of the engineers and firemen in this hot country. The engine is divided into three portions, the superstructure and two steam-driven bogies.

With this locomotive on the Rhodesia lines, the boiler is one of "Belpaire" type, thus providing a specially large steam capacity and the usual advantages for washing out.

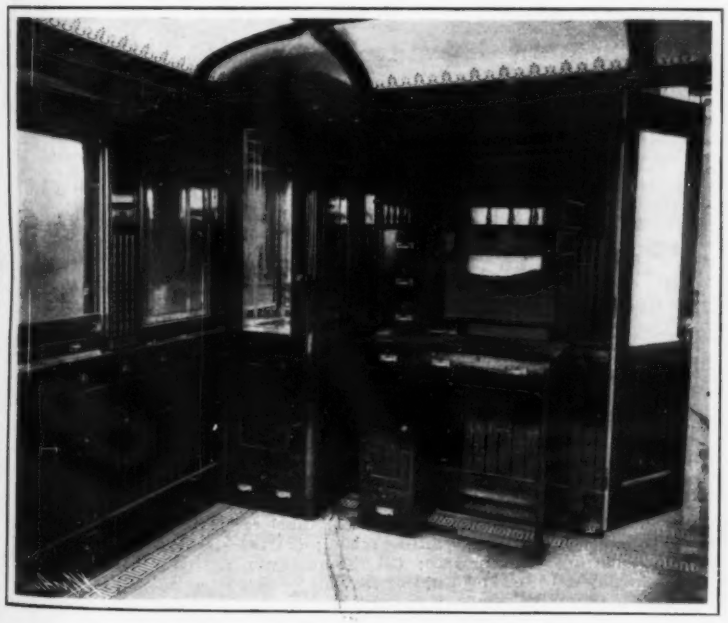
This engine was placed in operation in 1903 by the Rhodesia Railway Company, and has been found to handle twice the loads of the largest engine previously in use on the lines.

The success obtained by the "Kitson Mayer" engine has been found to be equally great on lines in Chili and

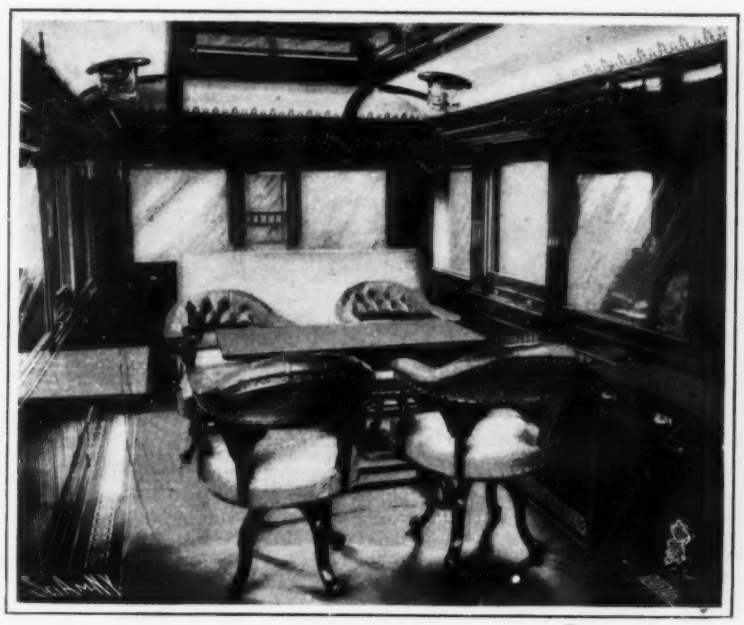
* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.



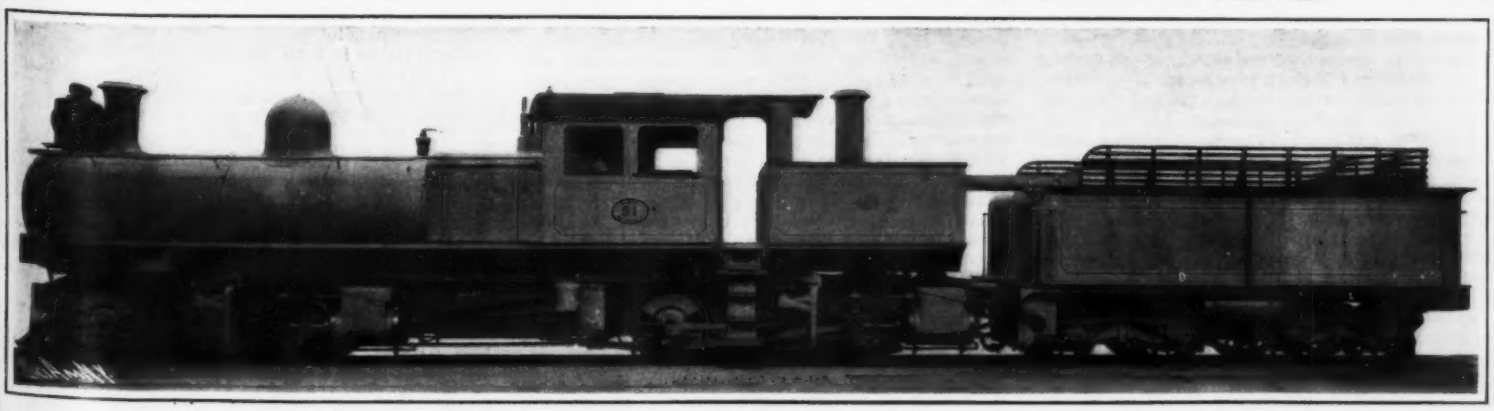
THE MEDICAL OFFICER'S CAR.



WARDROBE END OF LIVING ROOM, MEDICAL OFFICER'S CAR



LIVING ROOM OF DISTRICT OFFICER'S CAR.



KITSON LOCOMOTIVE USED ON THE RHODESIA RAILWAYS.

CARS AND ENGINES USED ON THE RHODESIA RAILWAYS IN SOUTH AFRICA.

Brazil, and it is likely that engines of this particular type will be further adopted in countries where heavy loads are required, where the grades are arduous, and the curves severe.

The superstructure consists of boiler, coal bunker, water tanks, and cab, which rest on two long girders, that are themselves carried at two pivot points on the six-wheel-coupled bogies. By this means the whole weight of the engine is upon the coupled wheels, and is on that account available for adhesion. It can be accurately adjusted by means of a special spring connection introduced at a selected position away from the center of the bogie, and as the wheel base of each bogie is not more than 8 feet 6 inches, the very large engine here illustrated, weighing as much as 72 tons, can pass round curves of 3 chains radius without injury to the permanent way.

In addition to the advantage of traversing these severe curves, the line of pull from the engine itself is kept in a position less likely to cause side resistance at the pulling end. Each bogie is complete in itself, being an engine with a pair of cylinders, valve motion, brake gear, sanding gear, etc., and bearing the weight of half of the superstructure on a recessed steel casting.

There are bolts passing through slot holes in these castings which form a connection between the bogies and the superstructure, and a further security against an excess of movement is provided by the addition of check chains. The mechanical details by which the power is supplied and controlled for each bogie have been carefully designed, and the steam is carried from the front end of the boiler by means of ball and socket joints to each pair of cylinders.

The exhaust of the front bogie is carried through the smokebox, and is sufficient to keep up the draft through the firebox and so maintain steam. The exhaust steam of the hind bogie is passed into the atmosphere, but could be utilized either for the purpose of increasing the draft or for an exhaust steam injector if required.

The engineer supplies steam to both sets of cylinders by one movement of the throttle lever. In the same manner he is enabled to reverse both engines, apply the brakes, and actuate the sanding gear by one movement of each of the handles concerned. There is no difference in the method of lookout or handling of the engine from that ordinarily followed.

The private cars on the Rhodesia Railway are constructed of teak framing, the match boarding below the window belt being of teak with sheet-steel panels above grained teak. They are designed especially so as to be suitable for the South African climate. The floor boards are laid diagonally and in two thicknesses, the space between being filled with teak sawdust to deaden the sounds. Each window is fitted with a plate of glass, wire gauze screen, and a blind in separate frames. The accompanying photographs illustrate the construction of the agent's private car, as well as that of the district officer's and the medical officer's. The glass frame of the window is provided with spring sash balances, and the blind and gauze frames are finished with springs and catches. The independent gauze frame is quite a new feature which is considered to be absolutely necessary for comfort, owing to the sand and dust storms which are prevalent in South Africa.

The body of the agent's car is divided into five compartments, consisting of living rooms, bedrooms, lavatory, kitchen, and a balcony at each end. The living room is provided with a woven rattan spring couch, sliding seat with reversible back, three removable armchairs, and flap tables. The general finish of this compartment is rich mahogany from the millboard panels and carved teak moldings and pilasters, while the floor is finished with linoleum.

The side ventilators in the car roof are operated with quadrant fixtures. Bronze basket racks are placed over the side windows, as shown. A Boyers speed recorder, placed in this compartment, is connected to the axle with a flexible metal belt. The recorder not only indicates at what speed the carriage is moving, but records the speed also.

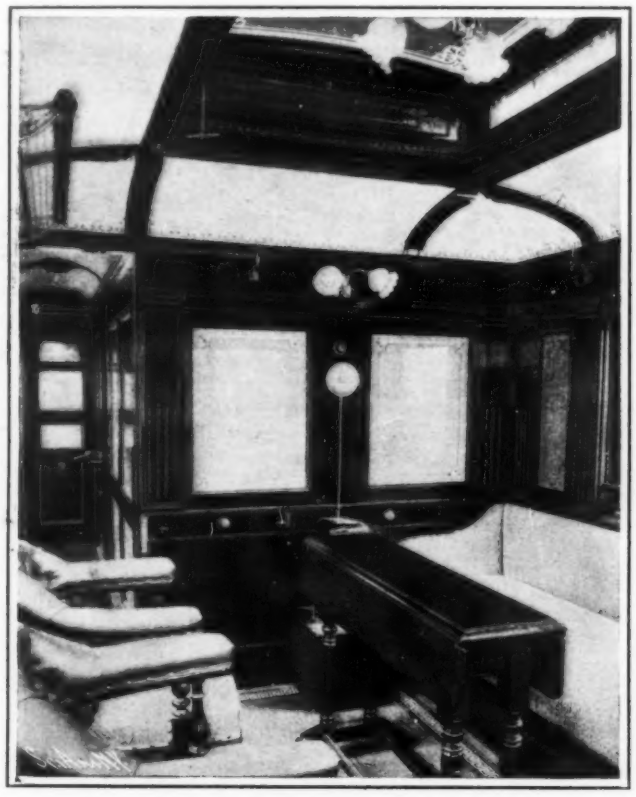
A corridor divides this compartment with the bedroom. This room is provided with a rattan couch similar to the living room. Over this is an upper berth, arranged to fold up against the roof with a spring pulley acting as balances. A dressing table finished with mirrors and drawers, besides a wardrobe with mirror door and small chair, are provided. The interior finish is similar to the living room. The lavatory compartment is fitted up complete with water closet having balanced lid and flushing tank, folding wash-hand basin, Pasteur filter, mirror, towel rail, and brush and comb rack, also sponge rack. The floor is covered with 3-pound lead, over which is a teak grating. The sides of the compartment to granish rail are lined with zinc, and above this to the roof are paneled with mill-board enameled dead white. A fifty-gallon water tank is located in the roof. The kitchen is fitted with an open and closed coal stove having two ovens and water boiler complete. The sink is provided with hot and cold water taps, and has a coal box beneath it. Cupboards, plate racks, and shelves are also provided. A water tank in the roof has a capacity of fifty gallons. This is connected to a tank in the under-frame by a pipe and force pump having a bore of 1¼ inches. The floor panel work is made up of millboard and molded teak, neatly decorated to suit the internal finish. A zinc-lined refrigerator is fixed under the living-room floor. All the compartments are lit with electric light by Stone's system of driving a dynamo from the axle, and storing by means of accumulators having a capacity of about 15 hours' stationary lighting. Electric bells in the kitchen are connected with push buttons in all compartments. The whole of the metal fittings are finished in bronze, and are of a high-class description. The underframe is composed entirely of steel sections. Bogies, including wheels and axles, vacuum brake, and draw and buffing gear, are similar to the Rhodesia standard practice. The axle boxes are of malleable iron, and the bearing springs are of exceptional length for flexibility and to insure easy riding.

The medical officer's carriage is similar in general outline to the agent's carriage, excepting that the underframe is mounted on four wheels only and that electric lighting is omitted. The body is divided into four compartments, viz., living room, surgery, lavatory, and kitchen, with a balcony at one end for the cook's use. The living room is fitted up complete with a woven rattan spring couch, two revolving arm chairs, flap tables, wardrobe with mirror front, writing desk with cupboards and drawers, and two basket racks over side windows. The general finish of the compartment is in rich mahogany, with millboard panels having carved teak moldings and pilasters.

The surgery is fitted up with hooks and rings in the roof. The vacuum brake valve and handbrake spindle are here also. The whole of this compartment is enameled white. The fitting up of tables, cupboards, racks, etc., is left in abeyance, so that the medical officer can have this done to suit his convenience. The lavatory compartment and kitchen are in complete accordance with that described for the six-wheeled saloon. Each compartment is provided with oil lamps of the most approved type. The district officer's carriage is exactly the same as the medical officer's, excepting that the "surgery" is omitted and the living room carried through to the kitchen partition.

These private cars were constructed by the Electric Railway and Tramway Carriage Works, Ltd., of Preston, Lancashire, England, and a special saloon car is now being constructed at this plant for the Rhodesia Railways which is 60 feet long and is fitted up in the most modern style with hot and cold water baths, shower baths, kitchen, bedrooms, electric fans, and electric lighting, while the compartments are to be heated by an independent hot-water system, and the berths are to close up out of sight.

KITCHEN OF MEDICAL OFFICER'S CAR.



CORRIDOR AND LIVING ROOM OF PRIVATE CAR.

INTERIOR VIEWS OF CARS USED ON THE RHODESIA RAILWAYS OF SOUTH AFRICA.

## FACTORS IN PAINTING WOODWORK.*

WHEN we were young in the paint business we fancied that if we could produce good material we would have no special troubles with it. However, experience soon dispelled this illusion and taught us that there are other things than the quality of the paint which affect the results to be obtained from its use. From our standpoint the following factors affect results in painting, viz., (1) the location of the structure, e.g., seaboard or inland; (2) the kind and condition of the surface; (3) the quality of the paint; (4) the workmanship of the painters; (5) the number of coats applied; (6) the amount of time allowed to elapse between coats; (7) the atmospheric conditions when the painting is done.

### LOCATION OF STRUCTURE.

Whether a paint is made to dry by oxidation, by evaporation, or by both, naturally there is a difference in its drying when used in the damp, saline atmosphere of the seashore or in the dry highlands of the interior; when used on the coast of the Gulf of Mexico or in the colder States of the North; when used in the pure air of the country or in the vitiated air surrounding structures in many towns and cities. Not only is the drying of paint affected by the location of the structure upon which it is used, but its working properties and durability as well. The viscosity of oil and varnish being affected by temperature, they will work more easily in warm climates than in cold. The durability will always be impaired by alternate exposure to wind and water; by exposure to sunshine and rainfall; deleterious gases, vapors and liquids; dampness, darkness, mechanical injury, etc. The paint for the finishing or top covering of any structure should be made to meet the special conditions of exposure to which it is to be subjected. Competent paintmakers can readily make protective coverings to withstand any

* From a paper read by Mr. Houston Lowe at a Pittsburg meeting of the Engineers' Society of Western Pennsylvania.

reasonable condition of exposure and use; but in order to do so, obviously they must know the conditions—e.g., we were recently called upon to make for a prominent railway system a steel tank coating to be used near the Gulf of Mexico. The engineer in charge informed us that there was so much water of condensation on the surface of the metal most of the time that it was only possible to paint between the hours of ten in the morning and three in the afternoon, and that he had to have a paint that would set (not dry and harden) in two hours, otherwise it would be impossible to secure fair adhesion. It was possible to make a paint to meet this condition; had we not known the condition, anything sent at haphazard would undoubtedly have proved a failure.

KIND AND CONDITION OF THE SURFACE.

Absorbent brick, soft lumber, corroded iron, or a rough surface of any kind will generally require a paint with a larger proportion of liquids to solids than hard lumber, clean steel, tin, etc. In one case the paint will be more or less rooted into the material underneath, and in the other it must be held almost wholly by surface attraction. Lumber contains water, sap, ligno-cellulose, and mineral matter. The two former are repellent of paint. As a rule, the heartwood of trees is more receptive to paint than the sapwood, a notable exception being yellow pine, the sapwood of which costs less than the heart and takes paint better; therefore, if protected by paint it will last longer in frame buildings. The railroad people who are progressive have found this out, and are rapidly substituting sapwood for heartwood in freight car construction. We are surprised to learn that many reputable architects in the Southern States still specify heartwood of yellow pine for siding upon houses of the best class; it is unfortunate that there seems to be a lack of understanding upon the part of educated men of the close relation which paint must bear to the surface which it covers, e. g., the wood, and the importance of specifying lumber that paint can stick to. There are said to be thirty-nine varieties of pine in the United States and numerous species of poplar, hemlock, cypress, etc., so that one can see that it is easier to design a paint for coating iron or steel than it is for coating wood. It may be a good idea to use common lumber or seconds for weather-boarding and then try to save it or hide it with paint, but we question the economy of it. With metals, when their temperature is less than that of the surrounding atmosphere, more or less sweat or water of condensation will always be found upon them. This is repellent of paint, as also would be any grease that might in any way get on the surface. In other words, paint will only stick well to a receptive surface, and a warm and dry surface will certainly hold paint better than a greasy, cold, or damp surface. It will also be noted that some metals not only hold paint better than others, but they also affect it differently. Paint does not adhere well to metallic zinc (galvanized iron). A paint spread upon clean metallic lead will dry much more quickly than one spread upon clean steel. On the other hand, it will wear longer upon steel than it will upon metallic lead. Another point regarding surfaces is this—viz., that rough surfaces hold paint better than smooth, and a paint upon rough surfaces seems to wear longer. The only reason for this phenomenon is that on a rough surface you get a greater thickness of layer than you do upon a smooth surface with the same number of coats. The sand blast offers a rapid, efficient, and economical means of cleaning steel and putting its surface into a receptive condition for paint, and we would be glad to see this method of preparation more generally employed when painting contracts are undertaken. So, too, we hope that it will not be long before architects, engineers, and builders realize that it is important to have sound, clear, dry lumber as a foundation for paint, and will insist upon the same in their specifications.

THE QUALITY OF THE PAINT.

The quality of any paint depends as much upon its physical characteristics as it does upon its chemical composition—e.g., with two linseed-oil paints that will show the same qualitative and quantitative analysis, the one of the greater viscosity will be the slower drying and the more durable of the two. This is because it will form a skin upon the surface that will be thicker and more impermeable to water and gases than the thinner paint. The corrosion of steel, the decay of wood, and the deterioration of paint are practically due to one and the same cause, viz., the combined action of carbon dioxide and moist air. Therefore that paint or coating will give the best protection which will be least affected by, and is the most impermeable to, a combination of these two things. To understand the nature of painting, we will first take up the subject of linseed oil, which, after centuries of use, to-day remains, from the standpoint of durability and drying, the best thinner we have for painting. Linseed oil in drying changes first into a sort of jelly and then into a solid leather or rubber-like substance which Mulder named "Linoxyn." This linoxyn is a wonderfully tough and durable substance. However, when linseed oil is spread upon a smooth surface, without the use of pigment, the skin formed will be less than 1-1,000 of an inch in thickness. Further, the skin so formed will be pervious to moisture. Pigment is therefore added to the oil for paintmaking, first for the purpose of thickening the skin formed, and second for the purpose of making the skin impervious to moisture. Dried paint may be looked upon as a fabric in which linoxyn is the chain and pigment the filler. Linoxyn is not quickly formed from linseed oil without dry air and the light, but when once formed is much more stable and much better able to resist atmospheric influences than linseed oil itself. In other words, wet paint is much more sensitive than dried paint. A fair quality of linseed oil when spread out in a thin layer on a smooth surface under favorable conditions requires from five to seven days to dry and harden. As this would be too slow for practical purposes, paintmakers and painters either add to the oil some pigment that will react with it to hasten drying, or they add to it some oxidizing agent like japan or some diluent like spirits of turpentine or petroleum naphtha, the two latter only serving as volatile extenders that more or less interrupt the continuity of the resultant film. So many books have been written on the subject of linseed oil that we will not attempt to take more of your time in the discussion of its nature and characteristics, but should you wish to pursue your investigations further, it will be a pleasure to cite authorities.

THE PIGMENT CONTENT.

We will now take up the subject of the pigment content of paint. From the practical standpoint, pigments may be divided into two general classes: first, those that react more or less with the binder, notably the carbonates and all lead compounds; and second, those that have no chemical action upon the binder, i.e., are inert, such as graphite, lampblack, barytes, silica, and sometimes ferric oxide, etc. Those of the former class produce the better drying and less durable paints; those of the latter class produce the slower drying and more durable paints. We work upon the theory that under coats should dry more quickly and harder than those above them, and that the difference in drying between adjoining coats should not be very great. On this theory, where best results are desired, we always recommend the use of red lead paint as a foundation coat on naked wood, and white lead paint as a foundation coat on bare wood. For the middle coat, where conditions will permit the use of three kinds of paint, we recommend the use of paint made from about equal proportions of active and inactive pigments with linseed oil. For finishing coats we always recommend the use of paint made from inactive or inert pigments with linseed oil. Among the best of this class may be noted graphite, charcoal, oxide of iron, powdered mica, and aluminium. The pigments named in this class are more stable and weather-resisting than linoxyn, therefore in the use of them you will find that the thicker your paints are the more durable will be the films resulting from their use when spread out in thin layers on steel. On the contrary, where durability is desirable, with active pigments like white lead, zinc white, etc., which are more affected by atmospheric influences than linoxyn, you will find that the thinner you use paints made from such pigments, consistent with fair covering of the surface, the better they will wear. On general principle, or as a common law, we would state the proposition as follows, viz., where inert pigments are used with linseed oil, the thicker your paints are, consistent with proper spreading under the brush, the better they will wear, and as a corollary to this, thin coatings, especially top ones, of paints made from pigments like white lead, chrome yellow, etc., will wear better than thick ones. You have doubtless noted how much better common paint, made from dull, inert pigments, wears on freight cars, barns, bridges, etc., than more delicate colors, made from active pigments like white lead, etc., wear on line cars, frame houses, and structures of that class.

WORKMANSHIP OF THE PAINTERS.

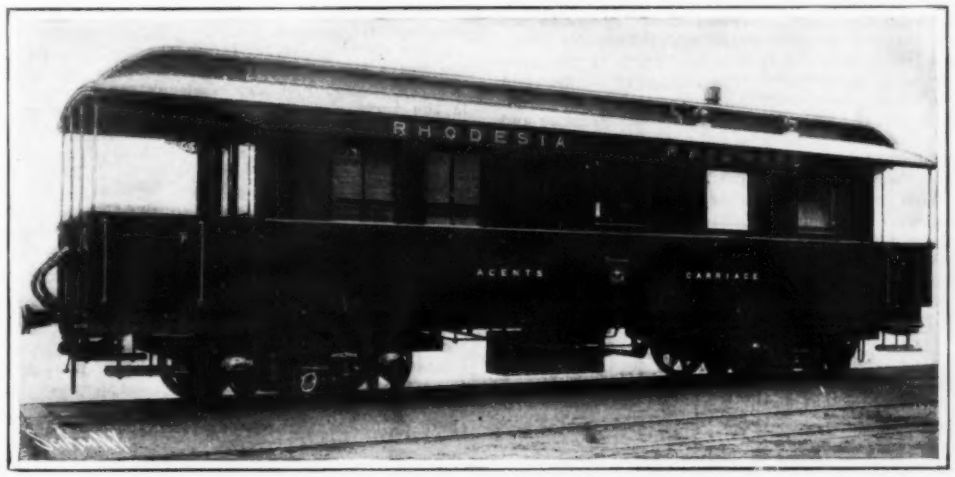
A good painter will often get better results with a fair paint than a poor workman will get with a praiseworthy one. The method of application is about as important as the quality of the paint used, for the reason that a layer of air and water which it may hold exists upon all surfaces. This layer of air prevents close adherence of the paint to the surface, and it can only be gotten rid of by thoroughly brushing the paint out onto the surface and into the body of the material underneath. A distinguished British painter and author writes: "The less paint that is put on at each operation consistently with a proper covering of the ground, the better will the ultimate result be." "Less paint and more painting," he impresses as a need "to quite 90 per cent of his painter students." The personal equation always counts in painting as it does in almost everything else. From experiments with an ocular micrometer in connection with a microscope, we find that single coats of the same paint may vary in thickness from 1-500 inch to 1-1,000 inch. The variations in thickness from these extremes and intermediate points are due to the varying pressure of the brush under the hands of the painter. Much of the poor work done nowadays results from the quality of the tools purchased by or supplied to the painters. We insist that a good workman to do good work must have good tools to work with; that is, brushes not over 3½ inches wide and full or thick with good, stiff bristles. For the highest class of work we prefer what they call down East "pound brushes"—that is, round brushes with good, stiff okatka bristles in them, not less than six inches long. With one of these properly bridled, a painter can do more and better work in a day than it is possible for him to do with the ordinary flat brush that is usually furnished him, and which costs little less. The good workman will always pay special attention to the coating of edges, and those parts of a structure where water and dirt will lodge, and to the filling in of all crevices, beads, and moldings, to prevent the incursion of water. These hidden parts are often the vital ones in bridges or in buildings of steel cage construction, and they are those which should have the most vigilant and constant attention.

THE NUMBER OF COATS APPLIED.

The durability of paint will be affected by the number of coats applied, e.g., two coats of paint will wear better than one; three coats of paint will wear better than two; and four coats of paint will wear better than three. The theory upon which we design coatings, both for wood and for metal, is, that the primer or foundation coat should be considered as structural material whose function is both to exclude air and moisture from the material underneath it and to form a receptive surface for subsequent coats. It is further our theory that in the sequence of coats this primer or foundation coat should dry more quickly and harder than any one covering it. Where it is desired to finish a structure in white, or in a light tint composed largely of a white pigment, we have reason to infer that it is wise to limit the number of coatings applied to three, exclusive of the primer; the reason for this limitation being that our knowledge includes no inert pigment which, when used alone with linseed oil, will have sufficient hiding power to serve as a satisfactory paint pigment. The consequence is that to produce a good paint in white or some light tint it is necessary to use pigments like white lead or zinc white that react with the oil and continuously weaken it until its power as a binder is finally destroyed. With paints made from inert pigments and linseed oil it is undoubtedly true that, provided a sufficient interval be allowed to elapse after each coat for it to dry and harden, the greater the number of coats and the greater the total thickness of the layer, the greater will be the degree of impermeability to air and moisture, and also the greater the degree of resistance to atmospheric influences.

AMOUNT OF TIME BETWEEN COATS.

Linseed oil in drying takes something from the air—viz., oxygen—and gives off something to the air—viz., carbon-dioxide and water. Mulder describes the process beautifully and calls it "the breathing of the drying oils." The things favorable to the drying of oil paints are light, pure, dry air, and moderate artificial heat. The things unfavorable to the drying of oil paints are a humid atmosphere, darkness, noxious gases, and low temperature. The amount of time which should be allowed to elapse between coatings of any given oil paint will vary so much with the location of the structure, the kind and condition of the surface, the quality of the paint, the atmospheric conditions when the planting is done and for the first few days after it is done, that it is obvious no set period of time can be named. However, a painter who is interested in his work can always determine whether one coating is fit to receive another by noting its luster, the time when the paint no longer sticks to the dry skin of the




A REPRESENTATIVE OFFICIAL CAR.

THE RHODESIA RAILWAYS OF SOUTH AFRICA.

finger, and the time when the layer cannot be moved under heavy pressure. Blistering, cracking, and peeling of paint are often due to the fact that under coats were too elastic when they were painted over. If a piece of work be painted coat upon coat of oil color before each coat is sufficiently dry, the movement and shifting of the under coats in their effort to obtain oxygen for their proper hardening will either rupture—i.e., crack—the top coats or lift them up in the form of blisters. Pearce, in his excellent book on painting, says that four days is not too much to allow for the proper drying of oil color which will nominally dry in twenty-four hours. The period may be shortened by additional driers; but a good rule is to allow all paint to stand four times as long as it takes to arrive at superficial dryness.

THE ATMOSPHERIC CONDITIONS WHEN PAINTING IS DONE.

Opinions as to the best time for painting differ largely; but nearly all the standard authorities concur in the opinion that a temperature of from 55 to 80 deg. and an atmosphere that is as free from moisture as possible favor the best results.

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[Concluded from SUPPLEMENT No. 1567, page 25113.]

## THE DIMENSIONS OF THE MARINE STEAM TURBINE.*

THE DETERMINATION OF THE PRINCIPAL DIMENSIONS OF THE STEAM TURBINE, WITH SPECIAL REFERENCE TO MARINE WORK.

By E. M. SPEAKMAN, Associate Member.

NUMEROUS empirical coefficients for approximating steam speeds and the corresponding number of rows are obtainable from experience, and are similar in use and value to the Admiralty coefficient; that is, while they represent a crude method of doing something that should be done more scientifically, they are very simple and capable of rapid handling. Being, however, based on long and costly experiments, much reticence is observed regarding their publication. Varying, of course, with the steam pressure and vacuum, the number of rows on one diameter would involve an excessive length of turbine and also inconvenient blade heights. It is, therefore, usual to divide the rotor into three or more stages, which have the advantage of shortening the turbine and reducing the number of rows. If $n$ = the fraction of power developed in the first cylinder or barrel, $N/n$ = number of rows in the first barrel, and with the alteration of diameter and increase of blade velocity in the succeeding stages, the number of rows on other barrels is so altered as to keep, for equal powers and efficiencies:

(Blade velocity)$^2$ × Number of rows = constant.

The vane speeds adopted in practice vary considerably; for some time 100 feet per second was regarded as a standard for the first row, and I think the Westinghouse Company at Pittsburg was the first to make

*Fig. 9.*

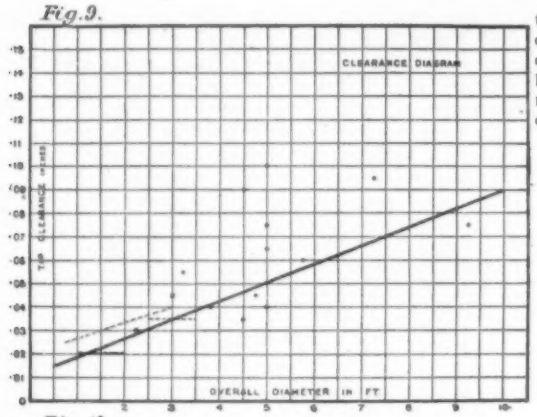
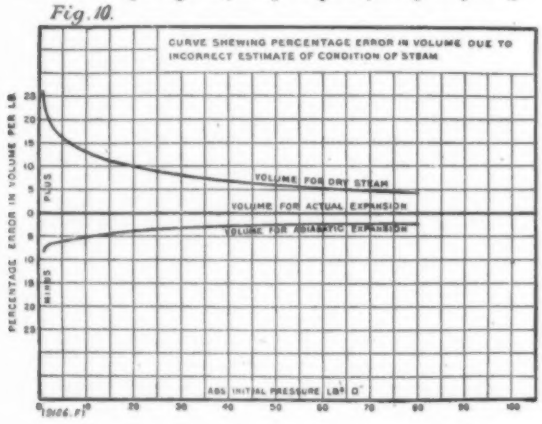



*Fig. 10.*


CURVE SHEWING PERCENTAGE ERROR IN VOLUME DUE TO INCORRECT ESTIMATE OF CONDITION OF STEAM
PERCENTAGE ERROR IN VOLUME PER LB.
PLUS
MINUS
VOLUME FOR DRY STEAM
VOLUME FOR ACTUAL EXPANSION
VOLUME FOR ADIABATIC EXPANSION
ABS. INITIAL PRESSURE LBS.

a radical departure in this, and adopt far higher speeds. The maximum vane speed used for the Parsons blading is, as far as the author is aware, about 375 feet per second in the low-pressure blades and 170 feet in the high-pressure blades of electrical turbines; the lowest speeds used are in marine work, and are only about one-third of these. To some extent blade speed is governed by blade height; the speed should be so modified that this may be at least 3 per cent of the mean diameter to reduce the proportion of clearance losses. Leakage over the tips of the blades is, perhaps, not so detrimental on account of actual leakage loss as in its superheating effect on steam between the row past which it leaks and the last row, because this reheating effect upsets calculations regarding openings by increasing the steam volume, and thereby affects the fluid efficiency. This leakage over the tips must be taken into account in designing reaction turbines. Temperature and diameter influence the clearance, and the stiffer the cylinder is to resist distortion due to heat, the less it may be made. A clearance diagram based on measurements off a large number of machines is given in Fig. 9.

In Table II. the vane speeds adopted in various classes of work are given, and the reduction in peripheral speed on account of the propeller reducing the revolutions, and the necessary proportion of blade height modifying the diameter, may be clearly seen. To this combined action is due the fact that only in the faster classes of vessels, or in those small types in which some propulsive efficiency can be sacrificed, is the turbine applicable. In slow cargo steamers, though the revolutions may be high enough, the power required is not sufficient to enable a reasonable blade height to be adopted, and it is this consideration—viz., proportion of leakage over blade-tips—that curtails the wider adoption of this type of turbine. For the same low peripheral blade speed other types of turbine are unsuitable on account of the impossibility of reducing the steam velocity sufficiently without abnormal weight and inefficiency.

The smallest size of marine turbine is usually larger than the average electrical turbine as far as power is concerned, and therefore does not meet with the same commercial considerations as the smaller sizes of the latter type. These are not designed for the same internal efficiency as the larger machines, chiefly on account of manufacturing cost, and they do not attain anything like the same efficiency compared with the Rankine cycle.

Speaking in reply to the discussion on his paper to the Institution of Naval Architects, in 1903, Mr. Parsons said that "for all practical purposes, while the steam is traversing each set (of blades), as shown, it behaves like an incompressible fluid, just like water would do, as the expansion is very small at each set. The frictional losses and the eddy-making losses would be practically identical within small limits with what they would be with water, and the actual forces would be in proportion to the density of the medium. . . . In the turbine blades themselves the efficiency is between 70 and 80 per cent."

Using this hydraulic analogy enables us to calculate the number of stages required in a different manner. The "equivalent head," due to the steam pressure, may be found, together with that at each row necessary to give the required velocity, from which both the number of stages and the coefficient of expansion at each stage may be worked out.

*Fig. 12.*

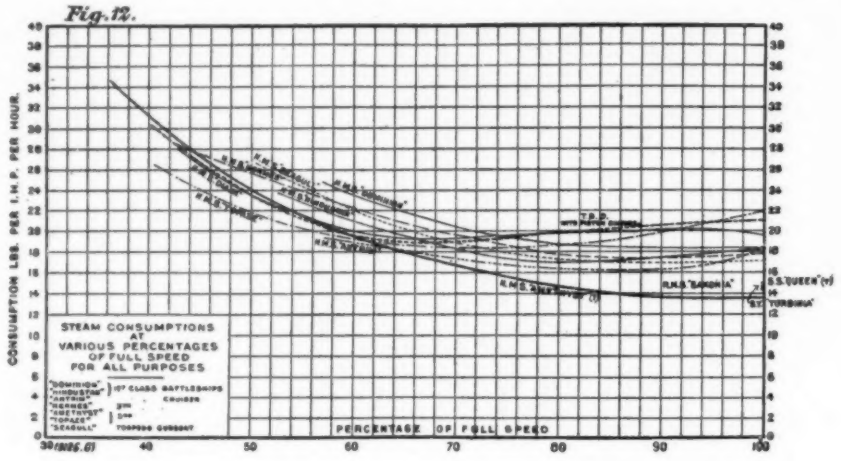


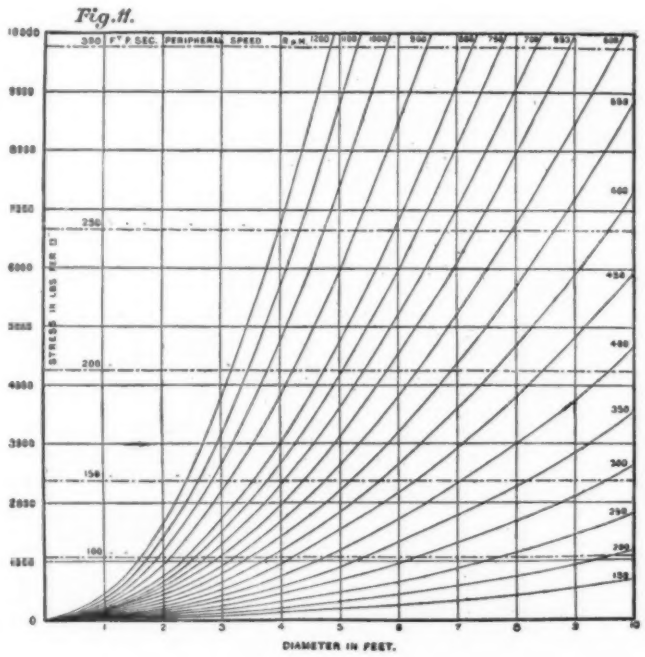

TABLE II.—*Marine Work.*

| Type of Vessel. | Peripheral Vane Speed. | | Mean Ratio of Vt — Vs. | Number of Shafts. |
|---|---|---|---|---|
| | High Pressure. | Low Pressure | | |
| High-speed mail steamers | 70 to 80 | 110 to 130 | .45 to .5 | 4 |
| Intermediate speed mail steamers | 80 ,, 90 | 110 ,, 135 | .47 ,, .5 | 3 or 4 |
| Channel steamers | 90 ,, 105 | 120 ,, 150 | .37 ,, .47 | 3 |
| Battleships and large cruisers | 85 ,, 100 | 115 ,, 135 | .48 ,, .52 | 4 |
| Small cruisers | 105 ,, 120 | 130 ,, 160 | .47 ,, .5 | 3 or 4 |
| Torpedo craft | 110 ,, 130 | 160 ,, 210 | .47 ,, .51 | 3 ,, 4 |

*Electrical Work.*

| Normal Output of Turbine. | Peripheral Vane Speed. | | Number of Rows. | Revolutions per Minute. |
|---|---|---|---|---|
| | First Expansion. | Last Expansion. | | |
| kilowatts | | | | |
| 5000 | 135 | 330 | 70 | 750 |
| 3500 | 138 | 280 | 75 | 1200 |
| 2500 | 125 | 300 | 84 | 1360 |
| 1500 | 125 | 360 | 72 | 1500 |
| 1000 | 125 | 250 | 80 | 1800 |
| 750 | 125 | 280 | 77 | 2000 |
| 500 | 120 | 285 | 60 | 3000 |
| 250 | 100 | 210 | 72 | 3000 |
| 75 | 100 | 200 | 48 | 4000 |

*Fig. 11.*

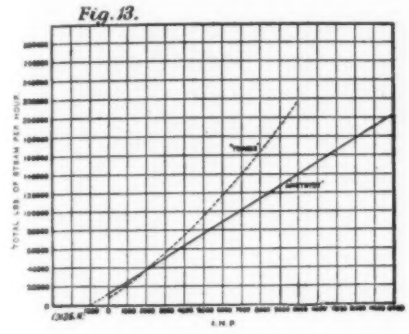



In the early marine designs, such as the "Queen Alexandra" and H. M. S. "Amethyst," the turbine drums were all made of the same diameter, and the higher speed necessary on the low pressures was got by running at considerably higher revolutions than on the high-pressure shaft; but, following up the increase in propeller efficiency found to be due to the use of larger screws, the speed for each shaft is now more

* Paper read before the Institution of Engineers and Shipbuilders in Scotland.

nearly equal, while the wing drums are made larger in diameter. The vagaries of the following wake, however, necessitate slightly different propeller dimensions on each shaft, or else slightly different revolutions with the same screws; and it is noticeable that in a triple-screw arrangement, the center screw being right-handed and the wing screws revolving outward, that the starboard propeller is influenced by the center one, and almost invariably revolves at a lower speed. In a four-shaft design, due to the varying wake values at different speeds, and possibly also to some unequal distribution of power, the outer screws run slower at low speeds, and faster at high speeds, than the two inner shafts; but exact data as to this, and the possibility of allowing for it in the design, are still wanting.

*Fig. 13.*



In all types of turbines—the Parsons, the Rateau, the Curtis, etc.—a certain ratio must be maintained between the blade velocity and steam velocity; and as steam acquires very high velocities by expansion, the blade velocity must be maintained either by the revolutions, or by large diameters, or both. As the weight increases very rapidly with the diameter, and extraordinarily so with the reduction in rotative speed, it is preferable to increase, if possible, the revolutions or the number of stages rather than the diameter, and especially should this be done in cases where, as in the Rateau or Zoelly type, the weight increases more rapidly in inverse proportion to the revolutions per minute and the diameter than it does with other types. To increase the revolutions it may be necessary to increase the number of shafts and propellers, thus reducing the power per shaft and the effective thrust through each screw. Increasing the diameter of the turbine adds largely to the constructional difficulties, especially of the cylinder.

Having obtained the number of rows and the diameter, the blading arrangement can be worked out in detail. The height of blade depends on the volume of the steam and the speed at which it is to flow, and also on the ratio of the area of exit openings between the blades to that of the annulus between spindle and cylinder, which is about one-third in normal blades. The necessary clear area to pass the steam being equal to volume ÷ velocity, and knowing this annular factor, say 3, for a ratio of one-third (or 2 for ½, etc.), then

$$\text{Height of blade in inches} = \frac{\text{Clear area in square inches} \times 3}{\text{Mean circumference in inches}}$$

The ratio of blade height to mean diameter should not be less than 3 per cent, or more than 15 per cent, because in the former the leakage will be excessive, and in the latter the bending moment on the blade becomes too great, and the radial divergence of the blades too much. The width of blade, the shape of section adopted, and the circumferential pitch are standard considerations, and affect the factor 3 given above. It is not proposed to enlarge upon them in this paper.

It may, however, be remarked that for $\frac{V\,t}{V\,s}$ greater than 0.6 the usual shape of Parsons's section, as shown in Fig. 5, should be modified to a somewhat different form of blade, with a sharper entrance edge. This section is not to be recommended, as, owing to the necessity of strengthening the blade sufficiently, the metal must be placed nearer the exit edge, thus increasing the angle between the face and the back of the exit edge of the blades, and giving, in fact, an inferior shape of opening compared with that obtainable with a blade section adapted to ratios under 0.6. If, for the present, it is sufficient to use the blade sections and packing pieces similar to those now adopted so generally, in Table III. can be found a list of widths for a given height, and the axial spacing of the rows. While this must be kept down to reduce the length of drum, it must be sufficient to allow for some play in overhauling; and sufficient clearance can be allowed here without affecting the economy. The openings between the blades to allow of the passage of the steam are very important, and must be carefully designed. The actual volume of the steam—not the volume per pound, as found in tables, or the volume due to adiabatic expansion, but the exact volume per pound at any point along the turbine—must be determined, in order to arrive at the desired adjustment of velocities. It is extremely doubtful whether the present blading arrangements give the best results; greater accuracy of calculation, and consequently improved pressure distribution and efficiency, seem likely to follow the use of a more mechanical blading construction.

*Fig. 14.*

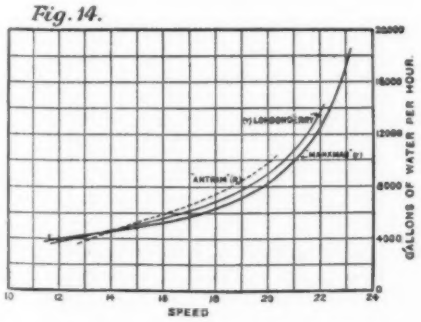



Fig. 10 shows the percentage error involved in using either the dry volume or that due to adiabatic expansion, compared with the correct volume corresponding to the actual expansion in a large turbine using dry saturated steam at the first row of blades and 27 inches vacuum. Attention must be paid to the effect of approximately adiabatic expansion and the consequent moisture in the steam.

For manufacturing convenience, as well as to allow for the expansion of the steam, the blade heights are stepped up; but no rule exists for this; the blades might be of one or of sixty-four heights, provided the blade openings are correct. It is, however, convenient to step them, as in Fig. 5, say, in eight steps of eight each, or four of sixteen—even nine of seven would do—and so avoid any great variation from the annular area factor 3, as shown above. To obtain heights and areas, it is best to plot off graphically, volumes, steam speeds, and clear areas required. The use of standard blade heights will then enable the number of stages and rows per stage to be determined. Wide differences can be made in any arrangement without materially affecting the economy. The best arrangement is largely a matter of convenience and experience.

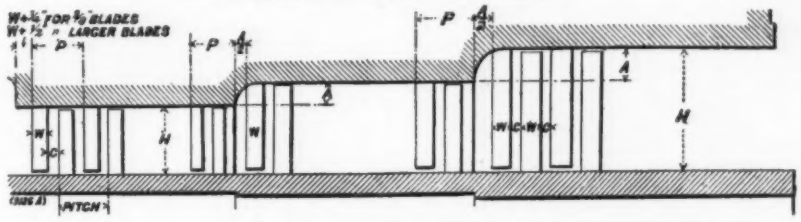
The material of which blades are usually made is a mixture of cheap brass, containing about 16 parts of copper and 3 parts of tin. Alloys containing zinc are extremely unreliable for high temperatures, but blades containing about 98 per cent of copper have been found very satisfactory for use with high superheats. More recently a material containing about 80 per cent of copper and 20 per cent of nickel has been adopted, and this is undoubtedly the best blading material existing. Steel blading, drawn in the same way as the usual brass section, has been used in the United States with fairly good results. The process of drawing turbine blades gives an extremely tough skin to the metal used, not only increasing the tensile strength, but greatly decreasing the chances of erosion.

It seems probable that the usual calking piece now adopted will be discarded in favor of a machine-divided strip, into which the blades may be fitted; and instead of the slotting, wiring, lacing, and soldering process at the tip, a similarly machine-divided shroud will be used, giving a far stronger construction, and enabling finer clearances and better workmanship to be obtained, at the same time considerably reducing the cost of manufacture and the risk of blade stripping.

The chief causes of the latter may be set down to bad workmanship in fixing the blades, defective blade material, excessive cylinder distortion (this is probably the most fruitful cause, and is a serious one, being due to bad design), whipping of turbine spindles (which is also due to bad design or bad balancing), wear of bearings (which is very remote), and the introduction of extraneous substances, such as water or grit. In fact, blade stripping may be said to generally occur from preventable causes. Small vibrations of very high frequency occasionally set up an action in certain rows of responsive length that fatigues the blade material, and causes the loss of blades without any fouling at all.*

Due to the action of the steam, an end thrust occurs in the direction of the propeller, which is advantageously used in partially balancing the propeller thrust, thereby reducing the size of thrust-block necessary. A margin must be allowed here, and the propeller thrust is not entirely balanced by the pressure on the annulus between the dummy-ring diameter, *D*, and the spindle, *C*, Fig. 5, plus the end pressure on the blades. For the diameter, *D*, to give the required annulus, as well as that of the propeller, the effective thrust must be carefully calculated; and experience shows that there is a drop in steam pressure varying from 10 pounds to 15 pounds per square inch between the pipe inlet to the high-pressure receiver and the first row of blades, which should be considered in designing this balancing area. The number of rows of dummy packing used varies, according to the designer's judgment, very largely, and may be modified according to the pressure and the clearance allowed—say 7-1000 inch to 15-1000 inch in electrical work, and rather more in marine work.

TABLE III.—STANDARD BLADING DIMENSIONS.




| | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. | in. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Height (*h*) | 1 | 2 | 3 | 4 | 6 | 8 | 10 | 12 | 15 | 18 | 21 | 24 | 30 |
| Width (*w*) | ⅜ | ⅜ | ⅜ | ⅜ | ⅜ | ⅜ | ⅜ | ⅜ | ⅜ | 1 | 1 | 1½ | 1½ |
| Pitch (*p*) | 1½ | 1½ | 1½ | 1½ | 2 | 2½ | 2½ | 2½ | 2½ | 3½ | 3½ | 3½ | 4 |
| Axial clearance (*c*) | ⅛ | ⅛ | ¼ | ⅛ | ⅛ | ⅛ | ¼ | ¼ | ⅛ | ⅛ | ⅛ | ¼ | ¼ |
| Section Number | | | | | | | | | | | | | |
| Spindle packing-piece No. | | | | | | | | | | | | | |
| Cylinder " " | | | | | | | | | | | | | |

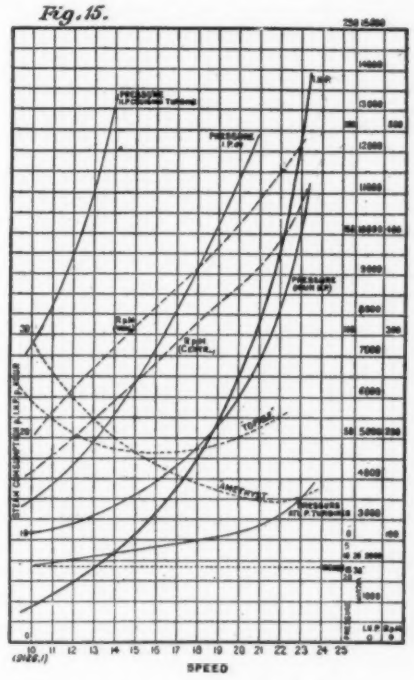
NOTE.—While the above represents general practice, it is obvious that such a table is largely arbitrary.

The dimensions of the astern turbine are arrived at in the same manner as those of the ahead, the efficiency being largely sacrificed on account of weight and space; generally the mean diameter is made practically the same as that of the high-pressure drum.

To a large extent the inferior maneuvering capabilities of the earlier turbine steamers were due to insufficient astern power.

It may be remembered that in a marine turbine the spindle is in compression and the cylinder in tension when working. In electrical turbines where the end-thrust must be eliminated by the use of balancing pistons, the spindle is in tension and the cylinder is balanced. The shafts between the turbine bearings and the drum must be made amply stiff enough, as well as strong enough, for any sag in the spindle will destroy the clearance. As will be seen from Fig. 11, the stresses due to centrifugal force are very low in the Parsons turbine, and, except in occasional low-pressure barrels, do not exceed 7,500 pounds per square inch, while at the high-pressure end they are usually under 2,000.

*Fig. 15.*




The pressure on the bearings in a turbine is only due to the weight of the spindle, plus the negligible addition, in marine work, of that due to any gyroscopic action; it may be taken as from 80 pounds to 90 pounds per square inch as long as the rubbing velocity does not exceed 30 feet per second. If it does, the pressure must be reduced so that the product of pressure × the velocity does not exceed 2,500 to 2,700. In land work, 50 pounds × 50 feet is very common. The friction heat of the bearings added to that due to conduction through the pedestals necessitates the use of large oil coolers, and in the case of very high temperatures, of special kinds of oil. If possible, the bearing temperature should not exceed from 140 deg. to 150 deg. Fahr., though the writer has known of 190 deg. Fahr. being used without trouble. In marine turbines this temperature is usually much lower. Rigid bearings are used for marine spindles—not the flexible type adopted in land work.

Space does not permit of more than passing reference to cylinders; but it would be difficult to exaggerate the importance of very careful design in this con-

* The writer had experience of this early in 1905, when a 5,000-kilowatt turbine, under test in one of the New York power stations, shed several rows of blades. This difficulty has also occurred in Europe, and can be circumvented by an alteration in the position of the lacing-strip.

nection. Cylinders, with heavy flanges on the center line, distort in a very curious fashion when heated with their axis horizontal, and measurements taken off a hot cylinder on a surface plate with micrometer gages reveal some very remarkable facts. When working, the temperature along the cylinder falls possibly from 400 deg. to 100 deg. Fahr. in a distance of 6 feet or 8 feet, and, unlike the reciprocating engine, this remains constant; the radial expansion is consequently more at one end than the other; while at any point along the turbine the tendency is to expand less at the flanges than at the top and bottom. For this reason ample clearance must be allowed; exactly what this will be when spindle and cylinder are hot is hard to say, but it seems most likely that the total clearance area will differ but little from what it is when cold.

The longitudinal expansion when hot is often very marked, and in all turbines necessitates provision for the resultant movement at one end. In marine work the after end of the cylinder is secured to the vessel, the engine-seating also performing the function of a thrust-block seat, while the forward end slides forward, taking with it the entire shafting. The thrust-block is at the forward end of the cylinder, and also performs the duties of an adjustment block for setting longitudinal clearances, to do which generally necessitates uncoupling the shafting abaft the turbine.

The difference in expansion between the cylinder and spindle, from the thrust-block to the dummy ring, may be the cause of serious difficulties in large marine turbines unless the closest attention is paid to this feature in the design; and "warming up" with these large cylinders needs possibly even more care than is essential with large piston engines.

On shipboard the turbine cylinders are practically under one's feet, and the radiation from them is very unpleasant, especially if there is any leakage from the glands. To all who are responsible for the lagging of cylinders and the system of ventilation in turbine engine rooms I would call attention to the possibility of their having to stand a watch of from four to six hours on the top of the high-pressure cylinder, such as is the case in the "Eden" or "Amethyst," the heat in the latter vessel being almost unbearable. With reciprocating engines one stands on a comparatively cool lower platform with the cylinders overhead, and with some chance of the hot gases rising clear; but in naval turbine work, under a low deck, this point has not met with adequate attention.

In the course of operation, more especially in marine work, where no superheaters are used, there is a distinct tendency for the turbine to be supplied with wet steam, the effect of which on the economy is very marked. Experiments that have been made show that the percentage increase in consumption is about twice that of the moisture in the steam. For instance, with 2 per cent of moisture in the steam at the first row, the consumption is increased about 4 per cent.

A considerable amount of data on the performance of turbines, compared with reciprocating engines for marine work, is now available. The Admiralty has had tested both cruisers and torpedo boat destroyers exactly similar but for their engines and propellers, and trials of the Midland Railway Company's steamers and other cross-channel boats have corroborated the results regarding economy obtained from the naval

## TURBINE STEAMERS.—GENERAL DIMENSIONS AND DATA.

| DATE. | VESSEL. | SERVICE. | OWNER. | BUILDER. | Length. | Beam | Depth. | Draught. | Speed. | Horse-power Equivalent. | Number of Shafts. | Screws per Shaft. | Revolutions per Minute. | Boiler Pressure. | Displacement. | Propeller Diameter. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1894 Rebuilt 1896 | Turbinia | Experimental | C. A. Parsons | C. A. Parsons | ft. in. 100 0 | ft. in. 9 0 | ft. in. .. | ft. in. 3 6 | knots 32 | I.H.P. 2,000 | 3 | 3 | 2200 | lb. 210 | tons 45 | ft. in. 1 6 | Only one screw, 25 in. in diameter, now fitted to each shaft. |
| 1900 | King Edward | Pleasure steamer | Turbine Steamers, Ltd. | Denny Brothers | 250 0 | 30 0 | 10 6 | 6 0 | 20.48 | 3,500 | 3 | 1 Centre 2 Wing | 595 C. 750 W. | 150 | 700 | 4 9 4 4 | Put in service July, 1901. |
| 1901 | Queen Alexandra | Pleasure steamer | Ditto | Ditto | 270 0 | 32 0 | 11 6 | 6 6 | 21.43 | 4,400 | 3 | 1 | 750 C. 1000 W. | 160 | 930 | .. .. | Put in service July, 1902. Very largely used for experimental trials. |
| 1898 | Viper | Torpedo-boat destroyer | Royal Navy | Hawthorn, Leslie, & Co. | 210 0 | 21 0 | 12 9 | 6 9 | 36.59 | 13,000 | 4 | 2 | 1150 | 240 | 280 | 3 4 | Launched Sept. 6, 1899. Ran ashore, and lost, during naval manœuvres in 1901. Trials made in 1900. |
| 1899 | Cobra | Ditto | Ditto | Armstrong, Whitworth, and Co. | 223 0 | 20 6 | 13 6 | 7 3 | 30.2 | 10,000 | 4 | 3 | 1050 | 240 | 450 | 3 0 | Sank at sea in Sept., 1901. |
| 1903 | Velox | Ditto | Ditto | Hawthorn, Leslie, and Co. | 210 0 | 21 0 | 12 9 | 7 3 | 37.1 | 7,000 | 4 | 1 | 880 | 240 | 440 | 4 0 | Reciprocating cruising engines on inner shafts, 74 in., 11 in., and 16 in. in diameter, with 3 9-in. stroke; 400 r.p.m. |
| 1904 | Eden | Ditto | Ditto | Ditto | 330 0 | .. | .. | .. | 38.8 | 7,500 | 2 | 1 | 940 | 250 | 370 | 3 3 | Launched February, 1902. |
| 1905 | Coastal destroyers | Ditto | Ditto | Thornycroft, Yarrow, and White | 175 0 | .. | .. | .. | 25.0 | 3,500 | 2 | 1 | 1300 | 220 | 225 | 3 0 | Twelve building. |
| 1905 | Ocean-going destroyers | Ditto | Ditto | Laird, Thornycroft, Armstrong, White, and Hawthorn, Leslie, & Co. | 250 0 | .. | .. | .. | 33.0 | 15,000 | 3 | 1 | 700 | 220 | 800 | 6 0 | Five building. |
| 1905 | Experimental destroyers | Ditto | Ditto | .. .. | 330 0 | .. | .. | .. | 36.0 | 20,000 | 4 | 1 | 600 | 250 | 1500 | 7 0 | Details under consideration. |
| 1903 | Tarantula | Steam-yacht | W. K. Vanderbilt | Yarrow | 152 6 | 15 3 | 8 4 | 5 0 | 25.36 | 3,200 | 3 | 1 | 1200 | 225 | 143 | (+4 8) (+4 6) | One 5-ft. screw now fitted to each shaft. |
| 1903 | Lorena | Ditto | A. L. Barbour | Ramage and Ferguson | 253 0 | 33 3 | 20 4 | 13 0 | 18.02 | 3,800 | 3 | 1 | (550 C. 700 W.) | 150 | 1400 | .. .. | Yacht measurement. |
| 1903 | Emerald | Ditto | Sir C. Furness | Stephen and Sons | 198 0 | 28 7 | 13 6 | .. | 15.0 | 1,400 | 2 | 1 | 900 | 150 | 900 | .. .. | Thames yacht measurement. |
| 1903 | Albion | Ditto | Sir G. Newnes | Swan and Hunter | 270 0 | 34 0 | .. | .. | 18.0 | 1,800 | 2 | 1 | 650 | 150 | 1250 | .. .. | Only twin-screw Parsons installation. |
| 1903 | Narcissus | Ditto | A. E. Mundy | Fairfield | 245 0 | 27 6 | 16 3 | .. | 14.5 | 1,250 | 2 | 1 | .. | 160 | 782 | .. .. | |
| 1905 | Royal Yacht | Ditto | H.M. King Edward | A. and J. Inglis | 310 0 | .. | .. | .. | 18 | 4,000 | 3 | 1 | .. | .. | 2200 | .. .. | In process of conversion from paddle engines to turbines. Vessel built in 1895 by Samuda. |
| 1905 | Mahrousah | Ditto | The Khedive of Egypt | A. and J. Inglis (re-building) | 400 0 | 43 0 | 26 6 | .. | 19 | 6,500 | 3 | 1 | .. | 150 | 2100 | .. .. | |
| 1903 | The Queen | Channel steamer | South-Eastern and Chatham Railway Company, London, Brighton, and South Coast Railway Co. | Denny Brothers | 310 0 | 40 0 | 25 0 | 10 6 | 21.73 | 8,500 | 3 | 1 | 480 C. 560 W. | 150 | .. | 6 0 5 7 | Screws originally arranged as in King Edward; 13 knots astern speed. |
| 1903 | Brighton | Ditto | | Ditto | 280 0 | 34 0 | 22 0 | 9 0 | 21.5 | 6,000 | 3 | 1 | 460 C. 510 W. | 150 | 1200 | 5 0 | |
| 1904 | Princess Maud | Ditto | | Ditto | 300 0 | 40 0 | 24 6 | 10 6 | 20.7 | 6,500 | 3 | 1 | 600 | 150 | 1750 | 5 0 | Bow rudder fitted. |
| 1904 | Londonderry | Ditto | Midland Railway Company | Ditto | 330 0 | 42 0 | 25 6 | 10 6 | 22.3 | 7,600 | 3 | 1 | 670 C. 750 W. | 150 | 1950 | 5 0 | |
| 1904 | Manxman | Ditto | Isle of Man Steamship Company | Vickers Sons & Maxim | 330 0 | 43 0 | 25 6 | 10 6 | 23.14 | 8,500 | 3 | 1 | 630 C. 690 W. | 200 | 2000 | 5 7 6 6 | |
| 1905 | Viking | Ditto | | Armstrong, Whitworth, and Co. | 350 0 | 42 0 | 17 3 | 10 6 | 23.53 | 9,500 | 3 | 1 | 610 W. | 160 | .. | 6 6 | |
| 1906 | Onward | Ditto | South-Eastern and Chatham Railway Company | Denny Brothers | 310 0 | 40 0 | 25 0 | 10 6 | 22.9 | 9,000 | 3 | 1 | 440 | 150 | .. | 6 0 | Sister-ship Invicta. |
| 1903 | Dieppe | Ditto | London, Brighton, and South Coast Railway Co. | Fairfield | 280 0 | 34 8 | 14 6 | 9 3 | 21.75 | 6,500 | 3 | 1 | 600 | 150 | 1380 | 6 0 | See Engineering, August 19, 1904. |
| 1906 | .. | Ditto | G. and J. Burns | Ditto | 350 0 | 40 0 | .. | .. | 25 | 9,500 | 3 | 1 | 430 | 180 | .. | .. | Three building. |
| 1906 | .. | Ditto | Great Western Railway Company | John Brown and Co. and Laird and Co. | 350 0 | 40 0 | .. | 14 0 | 25 | .. | 3 | 1 | .. | .. | .. | .. | |
| 1905 | Princess Elizabeth | Ditto | Belgian Government | Cockerill | 350 0 | 40 0 | .. | 9 7 | 24 | 12,000 | 3 | 1 | 493 | 180 | 1950 | .. .. | Astern speed, 16 knots; 415 r.p.m. |
| 1905 | .. | Ditto | Hamburg-Heligoland Steamship Company | Vulcan Company | 350 0 | 35 0 | .. | 9 10 | 23 | 6,000 | 3 | 1 | .. | .. | 3500 | .. .. | Curtis turbines. |
| 1904 | Lhasa | Persian Gulf to India; Intermediate | British India Steamship Company | Denny Brothers | 275 0 | 44 0 | 25 6 | .. | 18 | 6,000 | 3 | 1 | .. | 150 | 2170 | .. .. | Sister-ships Lunka, Lunka, Lanka. |
| 1901 | Loongana | Inter-Colonial Service, Tasmania—Melbourne | Union Steamship Company of New Zealand | Ditto | 300 0 | 43 0 | 25 0 | 12 6 | 20.2 | 6,300 | 3 | 1 | 550 | 150 | 2400 | 5 3 | |
| 1904 | Turbinia II. | Pleasure steamer; Lake Ontario | Turbine Steamship Company | Hawthorn, Leslie, and Co. | 263 0 | 33 0 | 20 9 | 9 6 | 19 | 3,500 | 3 | 1 | 650 | 180 | 1100 | 4 1½ | |
| 1905 | Mahero | Inter-Colonial | Union Steamship Company of New Zealand | Denny Brothers | 400 0 | 50 0 | 32 6 | .. | 17.5 | .. | 3 | 1 | .. | .. | .. | .. | |
| 1905 | Bingera | Australian Passenger | Union Steamship Company of New Zealand | Workman and Clarke | 300 0 | .. | .. | .. | .. | .. | 3 | 1 | .. | .. | .. | .. | |
| 1905 | Victorian | Atlantic Intermediate Service | Allan Steamship Company | Ditto | 540 0 | 60 0 | 42 0 | 27 6 | 19 | 12,000 | 3 | 1 | 275 | 180 | 13,000 | 8 9 | Also Virginian, built by Stephen & Sons. Weight saved by adopting turbines, 400 tons. Passengers increased 60. |
| 1904 | Carmania New Cunarders | Atlantic Mail | Cunard Company | John Brown and Co. and Swan and Hunter | 672 6 760 0 | 72 0 88 0 | 22 0 .. | 32 0 .. | 25 | 21,000 | 4 | 1 | 165 | 195 | 30,000 | 14 0 17 3 | Two building. |
| 1904 | Amethyst | Third-class cruiser | Royal Navy | Armstrong, Whitworth, & Co. | 360 0 | 40 0 | .. | 14 6 | 21,750 | 14,000 | 3 | 1 | 165 | 195 | .. | .. | See Engineering, November 18, 1904. |
| 1905 | Lubeck | Ditto | German Navy | Vulcan Company | 341 0 | 43 8 | .. | .. | 22½ | 10,000 | 4 | 1 | 450 C. 480 W. | 220 | 3900 | 6 6 | |
| 1905 | Salem | Scout cruiser | United States Navy | Bath Iron Works | 420 0 | 46 8 | .. | 16 6 | 24 | 16,000 | 4 | 1 | 410 | 250 | 3350 | 6 6 | |
| 1906 | Chester | Ditto | Ditto | Fore River S. & E. Co. | 420 0 | 46 8 | .. | 16 9 | 24 | 16,000 | 4 | 1 | 430 | 250 | 3750 | 6 6 | |
| 1905 | Dreadnought | Battleship | Royal Navy | Portsmouth Dockyard | .. .. | .. .. | .. .. | .. .. | 21 | 23,000 | 4 | 1 | 300 | 250 | 3750 | 6 3 | Curtis turbine |
| 1905 | Orion Class | Armoured cruisers | Ditto | Ditto | .. .. | .. .. | .. .. | .. .. | 24 | 28,000 | 4 | 1 | .. | 250 | 18,000 | .. .. | |
| .. | No. 219 | Experimental torpedo-boat | French Navy | Société des F. and C. Mediterranée | .. .. | .. .. | .. .. | .. .. | 24 | 1,500 | 2 | Various | 1800 | .. | 92 | Various | Designs still under consideration. |
| 1903 | Libellule | Ditto | Ditto | Ditto | 182 6 | 15 3 | 8 4 | 5 0 | 30.4 | 2,200 | 3 | Various | (675 R. 1800 T. | .. .. | .. .. | .. .. | Bateau turbines. See Transactions of the Institution of Naval Architects, 1904. |
| 1903 | Caroline | Ditto | Ditto | Yarrow | 125 0 | 14 0 | .. .. | .. .. | 20.5 | 2,300 | 3 | 1 | .. | 250 | 145 | .. .. | Brequet turbines. |
| 1904 | No. 223 | Torpedo-boat | Ditto | Normand | 125 0 | 14 0 | .. .. | .. .. | 26 | 2,200 | 3 | 1 | .. | 250 | 145 | .. .. | Astern speed, 16.7 knots. |
| 1904 | No. 224 | Ditto | Ditto | Ditto | 125 0 | 14 0 | .. .. | .. .. | 26.3 | 2,300 | 3 | 1 | .. | 250 | 145 | .. .. | |
| 1905 | S. 125 | Torpedo-boat destroyer | German Navy | Schichau | 200 0 | 23 0 | .. .. | 6 0 | 28 | 6,000 | 3 | 1 | 865 | 250 | 350 | Various | Curtis turbines. |
| .. | Revolution | Experimental steam-yacht | Curtis Marine Turbine Company | .. | 140 0 | 17 0 | .. .. | 7 0 | 18 | 1,500 | 2 | 1 | 650 | .. | .. | 4 6 | |

‡ Designed.

† On trial.

NOTE.—Also projected two vessels for the Great Central Railway Company, two for the Allan Steamship Company, two for the Metropolitan Steamship Company (New York and Boston service), and various foreign warships.

vessels. In Fig. 12 is given the steam consumption per unit of power of H. M. S. "Amethyst"* compared with that of several recent warships, and it is noticeable that only below from 55 to 60 per cent of their full speed does the consumption of the turbine exceed that of the piston engines. Very seldom do vessels steam below these speeds. Cruisers carrying relief crews to China or Australian stations usually proceed at about 60 per cent of full speed, and in the Atlantic maneuvers of 1903 nearly 80 per cent of full speed was maintained by the large fleets, while the Japanese battleships built in England made their first voyage to Japan at about 50 per cent of their full speed; at which ratio the consumption per indicated horse-power of both the "Hindustan" and "Dominion," representing very recent battleship construction by eminent builders, is materially in excess of that of the first installation of warship turbines (not including the destroyers). The total consumption of H. M. S. "Amethyst" and "Topaze," plotted on a base of power, is given in Fig. 13, while Fig. 14 shows that for the Midland Railway boats.† The progressive trials of H. M. S. "Amethyst" are shown in Fig. 15, and in view of the results obtained from these various vessels, the wholesale adoption of turbine machinery in the Royal navy is not surprising.

It is probable that the adoption of cruising turbines will be discontinued before long, and this view seems to be corroborated by the consumption trials of the Midland Railway steamers. Down to 60 per cent of her full speed, the "Manxman" required less water than the highly efficient "Antrim"; and with a different blading arrangement in the main turbines, such a result should be equaled, if not improved on, in war vessels. The additional complication involved with two cruising turbines, and their accompanying leakage and receiver losses, together with a considerable increase in weight and space occupied, largely modifies any advantages obtainable in the way of reduced consumption at large powers. An improved (and easily obtainable) design of main turbine blading should give a better result at the highest powers, practically the same at intermediate powers (as in the case of H. M. S. "Amethyst," from 14 to 20 knots) and only slightly inferior at speeds below 14 knots, while it will undoubtedly admit of greater ease of handling and be much simpler. In a triple-shaft arrangement the unequal distribution of power on the wing shafts, due to the use of cruising turbines, is a distinct disadvantage; the fluctuation in rotative speed, due to shutting off the high-pressure cruising turbine, may be seen from the trials of H. M. S. "Amethyst."

One of the low-pressure rotors of the Allan Line steamer "Victorian" is illustrated by the photograph exhibited. This rotor is 8 feet in diameter, and carries eighty rows of blades, varying successively from 1½ to 7 inches in length.

Another photograph shows the complete blade rings of a Willans turbine, the machine-divided construction of which, coupled with the strong form of shrouding adopted, presents such great advantages over the present unmechanical system that its universal adoption may be expected in the near future.

In conclusion, the writer would remark that it is impossible in the scope of a paper such as this to touch more than lightly on a subject which is of such vast importance. Many of the points dealt with above, such as cavitation, blading, cylinder design, etc., would require a volume to describe. While turbines, perhaps, are still in their infancy, they are already largely supplanting the reciprocating engine in many types of vessels. The next few years will undoubtedly show as great an improvement as has taken place since the advent of the "King Edward," barely five years ago, the more especially as the subject will, henceforward, be engaging the attention of all engineers instead of a few specialists; and that this improvement will more than justify the policy of the Admiralty and of the Cunard Company is already certain.

It should be a matter of some satisfaction to the members of this Institution that the present status of the marine turbine, if not absolutely due to the Clyde alone, is, at any rate, entirely a product of Great Britain.

* Since the above-mentioned results were obtained, the steam-piping has been altered, so as to permit the auxiliary exhaust steam to pass through the main low-pressure turbines when desired. This arrangement considerably decreases the consumption of low speeds, bringing the Amethyst's consumption below that of her sister-ships down to 10 knots, or about 45 per cent of full speed.

† Fig. 14 is compiled from the results given in Mr. Gray's paper to the Institution of Naval Architects, July, 1905.

## CATAPLEXY, OR FEIGNING DEATH.‡

MANY animals suddenly become motionless on the approach of danger. They are then said to feign death, but this expression, in so far as it implies a ruse, is misleading. An itch-mite, swimming under the microscope, stops when touched with a needle. Here the idea of a stratagem is absurd, as the creature can derive no advantage from immobility. But, as a mite has a distinct brain, let us take a simpler object, an amœba, which retracts its pseudopodia on the slightest disturbance. Such a drop of protoplasm, whose mentality barely reaches the height of a nervous reflex, is surely incapable of feigning death.

These examples show that unusual stimuli cause even the lowest animal forms to contract and become motionless, and it might reasonably be expected that this primitive impulse would be greatly intensified and perfected in some higher animals, while in others it would be entirely lacking, because useless.

That higher animals may become motionless under the influence of unusual conditions, especially such as cause intense fear, is suggested by the common expression "stiff with fright." This effect of terror, which is known as cataplexy, is analogous to the effect of unaccustomed stimuli on mites and amœbæ. The first experiments on the subject were published by Athanasius Kircher in 1646. He observed that a fowl, laid on the ground with its feet tied together, would, after some ineffectual attempts to escape, lie perfectly still. Then, if a chalk line were drawn on the ground, straight from the fowl's head, and its legs were unbound, it would remain motionless despite attempts to drive it away.

FIG. 1.—FINCH IN CATAPLECTIC STATE.

The experiment has been repeated, and extended to other animals, by many later investigators. The chalk line is useless. The chief condition of success is that the animal be seized suddenly and firmly held for a time. In this way cataplexy can be induced in many birds, guinea pigs, frogs, squirrels, moles, etc.

The same phenomenon is often observed in wild life. It cannot be a means of defense because usually the immobility, occurring at the moment of greatest danger, is fatal to the animal. For instance, the partial paralysis which, according to Prince von Wied, the sight of a venomous snake induces in Indians must be highly inconvenient.

Besides, it has often been observed that lizards pursued by snakes at first seek safety in flight but, when they find escape impossible, become motionless and seem to await death. Lizards appear to be peculiarly subject to cataplexy, which Preyer induced in some large lizards by quickly turning them on their backs, to the astonishment of the conjurors who were exhibiting them. Mice, squirrels, and other small animals, also, are fascinated and paralyzed by snakes, whence the immemorial popular belief in the hypnotic and magical powers of serpents. The fable of the basilisk probably rests on the same foundation. Pliny mentions, in his Natural History, an African animal, called Katablepas (looking downward), which carries its head bowed to the ground, fortunately for the human race, for whoever looks into its eyes dies instantly.

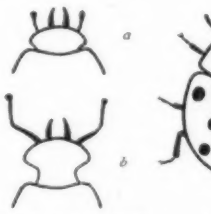


Fig. 2.—Burying beetle (Hister). *a*, cataplectic; *b*, normal.

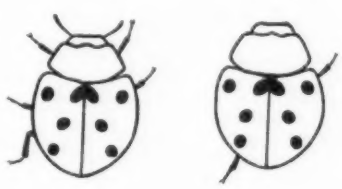


Fig. 3.—Ladybird in Cataplectic State.

Hunters frequently observe cases of cataplexy. Preyer says: "I have often seen partridges which had been shot in the leg fall to the ground, lie motionless for a considerable time, and then fly away. There can be no doubt that they had fallen into cataplexy when shot. Deer struck by glancing bullets also remain motionless. Even when they fall they are often found to be not mortally wounded but merely paralyzed by fright."

Hunters of certain animals reckon upon the aid of cataplexy. In Iceland, when the young swans come from the interior to the coast in autumn, they are greeted with a tremendous uproar, which causes them to fall to the ground, where they are easily captured. In German Southwest Africa the Hottentots employ a similar method in hunting the "springhaas," Cape jerboa or Cape hare. They beat the bush by moonlight, and, when they see a "hare" creeping from its hole, throw themselves on the ground and raise a horrible din. The poor beast, paralyzed by fright, remains motionless until the hunters creep to it on all fours and kill it with their clubs.

From these examples it is evident that cataplexy is not always beneficial, for immobility does not assure safety unless it is combined with other favoring conditions. If, for example, an animal possesses stout armor, within which it can retract its head and limbs, immobility may be of great service to it. The best and most familiar case in point is that of the tortoise. Darwin describes the giant tortoises (*Testudo nigra*), formerly so numerous in the Galapagos Islands, as hissing at his approach, retracting their heads and legs, falling noisily to the ground, and lying as if dead.

Fig. 4.—Dung-beetle, dead.

Fig. 5.—Dung-beetle in cataplectic state.

Often he seated himself on the animal's back and slapped it until it awoke and crawled off with him, but he adds that he found it difficult to maintain his equilibrium. Among other animals which act in a similar manner, and likewise to their advantage, are mussels, snails, hermit crabs, caterpillars, tube-worms, wood-lice, hedgehogs, and armadillos.

In the Revue Scientifique, last year, Piéron asserted that the case of insects which "feign death" is essentially identical with that of tortoises. Most of these insects also have strong armor beneath which the tender limbs can be retracted, thus reducing the area of surface exposed to attack. But, in the first place, not all insects retract their limbs in the cataplectic state. Darwin has pointed out that with many the simulation of death is imperfect. Among these are the burying beetles (*Histeridae*) so abundant in spring. Their popular German name, *Stutzkaefer*, or balking beetles, is derived from their habit of stopping short on encountering unfamiliar objects. One which I observed stood motionless sixteen seconds on coming to a wall or chair-leg or when I rose to my feet beside it, but it did not always entirely retract its antennæ. Many of the little beetles so often seen running along sandy paths stop from half a minute to two minutes when startled by a footstep or otherwise, but they retract neither their antennæ nor their legs. Another novice in the art of feigning death is the ladybird. This pretty little creature sometimes remains motionless ten minutes, retracting an indefinite number of its appendages and leaving the rest exposed. Many pages could be filled with similar examples.

Hence it is not true that cataplectic insects always retract their limbs in order to diminish the exposed surface. Besides, such diminution would be of questionable advantage against large enemies. A bird does not seize a beetle by the leg but swallows it whole. Small enemies, such as ants, on the other hand, can attack a limb even when it is pressed close to the body. I think, therefore, that the cataplectic phenomena of insects are not directly comparable with those of tortoises and other armored animals.

That the cataplexy of insects is not a ruse appears from the fact that it usually terminates long before the danger is past. Besides, the attitude assumed is generally very different from that of death. For example, the limbs of the dung-beetle (*Aphodius*) are extended in death, while in cataplexy they are retracted.

Insects exhibit great variety in respect to cataplexy. Some species, including the most active and most capable of self-defense, never fall into that state and among species that normally do so individuals are found that do not. Another interesting fact is that many individuals can be almost cured of the habit by familiarizing them with disturbance. I have often observed that beetles which at first stopped short at every alarm proceeded calmly on their way after repeated disturbances. The duration of immobility also diminishes when cataplexy is often induced. A carrion beetle (*Silpha atrata*) at first remained motionless thirty-five seconds, but repeated cataplexy shortened the period to fifteen seconds. Herrera has also observed cures of cataplexy by repeated disturbance. There are many species, however, to which this does not apply.

All these things indicate that cataplexy is of reflex character, and analogous to swooning. This view is confirmed by the fact that immobility is usually not absolute. A ladybird lay quite still for six minutes, then moved its forelegs, feebly at first and then more energetically. A minute elapsed before the hind legs moved, and two more before the insect ran away. Its first steps were uncertain and staggering. I have observed similar phenomena in individuals of many species. So the usual assertion that the insect awakes and escapes suddenly is not universally true. The first movements are often of a trembling, convulsive character.

Cataplexy, furthermore, is affected by environment and bodily condition. Once I found a beetle which had lost a leg and a wing cover. When touched it lay with limbs extended and awoke in four seconds, though normal individuals of its species remain long motionless, with retracted limbs. Another beetle, when near death from starvation, could not be brought into cataplexy.

Cataplexy is also prevented by decapitation. This fact proves that the brain plays an essential part in the phenomenon. Beheaded pine-weevils (*Hylobius* and *Otiorhynchus*), when touched, continued to move, usually backward.

According to Piéron, cataplexy depends on the absence of a hiding place. He found that beetles (*Dermestes* and *Gestrupes*) usually fled to the nearest refuge, falling into cataplexy only when no shelter was at hand. When turned on their backs, however, they always lay motionless, with legs drawn up, for a considerable time, finally righting themselves after protracted efforts. If touched during these struggles they relapsed into immobility. The disturbance lost its effect by frequent repetition, and a prick with a needle awoke the insect instantly.

But though I have observed more than one hundred species I have never detected the slightest effect of the presence of a hiding place. Dung-beetles (*Geotrupes*) surrounded by a ring of dung behaved precisely as they did in the absence of shelter. There is a red species that abounds in cow dung. When the crust of their paradise was removed they were found lying motionless on the surface. If the presence of shelter prevents cataplexy they should have buried themselves at the first alarm, as they did on awaking from their swoon.

Of the cases in which cataplexy is of advantage to

‡ Condensed from Dr. Walther Schoenichen in Prometheus.

its subject the most important are those of "protective mimicry," in which the animal imitates a plant or inanimate object. What benefit would a walking-stick insect derive from its striking resemblance to a twig if it should betray itself by rapid movement in the moment of danger? The ability to become motionless is a necessary part of such mimicry, and we may assume that in these cases the tendency to cataplexy has been greatly developed by natural selection. It is not surprising, therefore, that we find in these species the greatest experts in the art of feigning death.

Another group with very strong cataplectic tendencies includes animals that defend themselves by exuding poisonous or nauseous substances. Even in mammals in which cataplexy had been artificially induced Preyer observed vigorous and long continued peristaltic motion of the intestines, which often resulted in evacuation of the bowels or bladder. Fowls, ducks, and Guinea pigs defecate repeatedly and copiously during the otherwise complete immobility of cataplexy. In larger mammals, including horses and human beings, evacuation may be induced by fear. Clearly analogous to this is the exudation of nauseous blood from the knee joints of ladybirds and oil beetles (*Meloidae*) in cataplexy. According to Taschenberg the hornet fly (*Asilus*), when touched, exudes an extremely offensive liquid and falls into cataplexy.

The immobility assumed by certain animals when hunting their prey cannot be attributed to fear or cataplexy. Among these animals are the cat tribe, crocodiles, pikes, sea-horses and other fishes, and many lizards and snakes. To this class belong also all animals which are endowed with "aggressive mimicry," or which imitate lifeless objects in order to deceive their victims.

It appears, then, that immobility plays various parts in animal life. To some creatures it brings death by depriving them of the ability to escape, while to others it, in conjunction with armor, offensive excretions, or mimicry, affords protection, and to some beasts of prey it is indispensable. Thus Nature uses the same means for the attainment of different ends, just as she often employs various devices for the accomplishment of the same result.

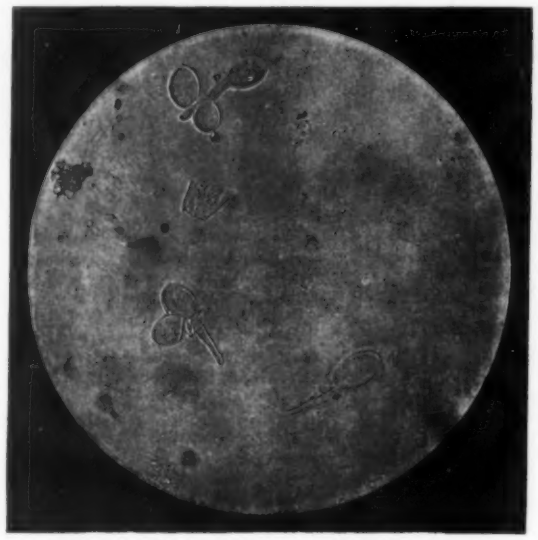
## THE CULTIVATION OF THE MOREL.*

By JACQUES BOYER.

THE morel (*Morchella esculenta*) is distinguished from all the other edible fungi of France† by its peculiar appearance. Its pedunculate, deeply pitted head, of which the depressions are sometimes regular, but occasionally assume the appearance of mere furrows with wrinkle-like interstices, prevents it from being confounded with any poisonous species of fungi. Its savory and fragrant flesh causes it to be highly prized by gourmets; and so, when the pale yellow and brown morels make their appearance in the woods under the influence of the spring showers of April, the peasants hasten to gather them in order to sell them at a remunerative price to the dealers in early fruits and vegetables. Unfortunately, it is a treat that mycophagists alone are capable of enjoying, since these honeycombed discomycetes do not grow in so great abundance as the boleti and cantharelli. Certain mushroom growers once tried to cultivate them, but did not succeed in obtaining encouraging results. However, along about the year 1872, a man named Geslin, by sowing some fragments of morels in an artificial soil composed of one-fifth rotten wood, two-fifths of earth taken from a place where these fungi grew, and two-fifths of rich earth, obtained a small crop for several years in succession.

This process was not based upon any scientific data, as were the researches of Mons. Charles Repin, having for their object the artificial culture of the morel from the spore. This scientist proceeded as follows: He took some glass tubes forty inches in length and one inch in diameter and filled them with vegetable material reduced to the state of humus (rotten wood, dead leaves, etc.). After a preliminary sterilization, he put some spores in one of the extremities of the tube, after which germination took place very rapidly. At the end of twenty-four hours the mycelium made its appearance, at the place where the spores had been deposited, with the aspect of a fine white down, of which the filaments ramified in the vegetable mold, and in a few weeks extended throughout the entire length of the tube. Into the end of the latter was then inserted the extremity of another and identical tube. When the operation was conducted under protection from mold, the propagation of the mycelium was continued into the second tube; but, in case of contamination, the mycelium vegetation perished. Therefore, in order to prevent the invasion of the noxious mold, it was important to select as an artificial soil some sort of vegetable débris of which the fermentable substances had disappeared as a consequence of decomposition. A few months later on the filaments of the mycelium (which are represented in the accompanying micrograph at the beginning of their growth from the spore) were seen to be more voluminous, and sometimes even there were observed felted masses that had resulted from the agglutination of various filaments. With age, the mycelium became capable of resisting the effect of mold, and after that it was possible for M. Repin to establish open ground cultures in the country. In imitation of the process employed with the common mushroom (*Agaricus campestris*), he prepared masses of vegetable mold of varying composition which he buried in trenches, and here and there inverted adult spawn taken from his tubes. Several springs passed without the appearance of a single morel upon the beds; but in 1900 and 1901 half a dozen of the succulent fungi appeared upon a compost of apple residua and around a stratum of dead leaves rendered alkaline by carbonate of soda and buried in a silo five years previously.

For the practical cultivation of the morel the essential thing seems to be to know what are the substances necessary for the nutrition of the fungus in the very complex media mentioned above. In a recent communication to the Academy of Sciences of Paris (April of last year), M. Molliard favors fermentable sugars. M. Repin thinks that it is necessary to have recourse exclusively to compounds of the cellulose group. The co-operation of a microbe, however, appears to be indispensable in order to permit the morel to pass through the cycle of its development. Thus would be explained why it is that this excellent cryptogam, like a number of the higher fungi, appears only at one time of the year, its vegetation being connected with the season phases of the microbian life of the soil. However this may be, the problem of the artificial production of the morel is now solved scientifically, and mushroom cultivators may soon be raising this esculent on a large scale, to the great joy of the gastronomers of the two worlds.



GERMINATION OF THE SPORES OF THE MOREL.

THE MOREL (MORCHELLA ESCULENTA).

* From American Homes and Gardens.

† The morel occurs, under a variety of forms, in various parts of the world. It is more or less plentiful in this country. As it dries very readily, and may be kept for some time, it is much used by European cooks for flavoring gravies. It is also dressed in various ways when fresh, and makes an excellent dish when stuffed with finely minced white meat. It may likewise be advantageously employed, instead of mushrooms, for making catchup. Morels are particularly fond of burned soil, and the collecting of them is so profitable to the peasants in Germany that the latter were formerly in the habit of setting fire to the woods to encourage their growth, till the practice was made punishable by a special law.—ED.

## UNSCIENTIFIC AND SCIENTIFIC DIVINING RODS.

By the Late GEORGE M. HOPKINS.

NOTWITHSTANDING the tendency of scientific knowledge and general enlightenment to dissipate superstition, the proportion of believers in certain kinds of demonstrations attributed to the supernatural is beyond belief; yet when we find, on investigating the subject, that many coincidences have occurred which seem to establish the claims of the advocates of such beliefs, it is no wonder that some of these notions gain credence, especially in view of the fact that the majority of unsuccessful experiments are never made known.

The divining rod—so called—is a very ancient device, but the belief in its efficiency is as strong to-day as it ever was, yet there is no scientific reason why it should be of any use whatever for any of the purposes to which it is applied. The ancient divining rod (Fig. 1) consisted of a forked twig of hazel, apple, or any fruit-bearing tree. It was held in the hands with the branches both lying normally in the same horizontal plane, with the crotch pointed either toward or away from the body of the operator. It was carried in this position over the ground, and whenever the forked twig bent downwardly it indicated proximity to water, minerals, or metals. The same performance is gone through with in these times, and we often hear of remarkable successes attained by modern operators. These successes are due partly to the good judgment of the operator, but mostly to sheer luck or chance. The dipping of the rod is not due to the action of the water or minerals, but to the voluntary or involuntary movement of the muscles of the hands and arms. If we assume that the operator is honest, we must admit the movements to be involuntary. In using the rod the hands are held in a strained, unnatural position, which renders it very difficult to hold the twig for any great length of time in the prescribed position without causing the muscles to twitch and thus compel the branch to dip.

The mineral rod illustrated in Fig. 2 is formed of a tube preferably, though not necessarily, of bamboo, with compartments at its ends. In one compartment is placed a piece of loadstone, and the other is partly filled with quicksilver. Both ends are corked and the instrument is held as shown in the cut. When the loadstone end dips it is supposed to indicate iron, but when the quicksilver dips it is taken as an indication of precious metals.

Although it does not seem advisable to multiply the accounts of these unscientific and worthless instruments, still, to convey an idea of the variety of devices of this class in existence, one more example is illus-

trated. The instrument consists of a small bottle suspended by a string and covered with thin cloth tied around the neck of the bottle. A specimen of the metal or mineral sought for is placed in the bottle. The string by which the bottle is suspended is held by the hands as steadily as possible. The bottle first revolves in one direction and then in the other. When it stops it begins to oscillate like a pendulum. The line of vibration is supposed to point to the object sought. The operator carries the device in the direction indicated until vibration ceases; the point where this occurs is the spot where the mineral or other substance looked for is to be found. If several different substances are looked for, a sample of each must be put in the bottle.

It is needless to say that all these devices and methods are devoid of any scientific principle, and if they ever give indications that lead to a find, it is either accident or coincidence. In the case of the last instrument described, the string naturally untwists when the downward pull of the weight comes upon it, and the acquired momentum of the revolving bottle causes it to continue to revolve after the string is untwisted, and twists the string in the opposite direction. The torsion thus produced revolves the bottle in the opposite direction, and so on until equilibrium is established. This will take some time; perhaps a half hour or more. At the expiration of this time the hands of the operator are so tired as to be incapable of holding the string steadily, and as a result the oscillations follow.

As to the scientific divining rods—if such a term can be applied to scientific instruments—the simplest of these is the miner's compass, shown in Fig. 4, and

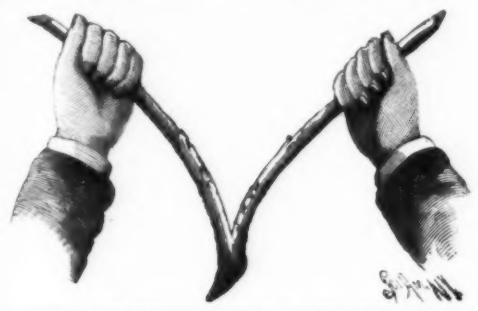


FIG. 1.—FORKED TWIG DIVINING ROD.

familiar to most readers of this article. It is simply a magnetic compass needle arranged to swing in a vertical plane. Its pivots being jeweled, it swings freely and points to any body of iron or magnetic ore contained in the earth. It is operative for a considerable distance, and has been used for years for locating iron mines; but it is of no use whatever for other than magnetic metals or ores.

In Fig. 5 is shown an instrument devised by the writer, in which a coreless induction coil of peculiar construction is used in connection with the telephone for indicating the presence of metals. The induction coil consists of a primary coil, preferably of rectangular form, made of coarse wire, No. 18, and connected with a rapid automatic circuit breaker and battery.

FIG. 5.—ELECTRICAL ORE FINDER.

The secondary coil is made of fine wire, No. 36, and is arranged exactly at right angles to the coarse wire coil. A telephone is connected with the secondary coil. If the primary circuit is continuously and rapidly interrupted while the coil is not in the vicinity of any metal or magnetic material, no sound will be heard in the telephone, as all the inductive influences are equal and opposite; but when the coil is held in proximity

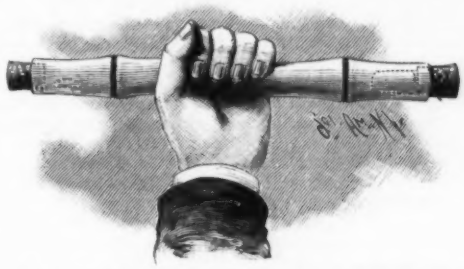


FIG. 2.—ROD FOR IRON AND PRECIOUS METALS.

to a body of metal or magnetic ore, this equilibrium is disturbed and the sound is heard in the telephone.

The distance through which this instrument is operative depends upon the diameters of the coils and the

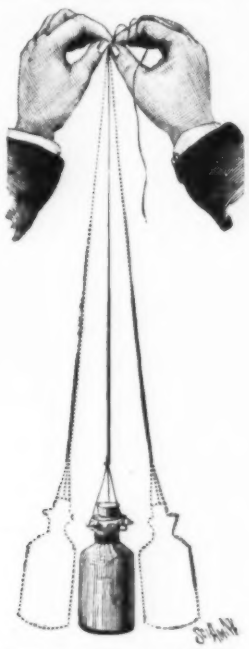


FIG. 3.—GOLD FINDER.

strength of the current used in the primary coil. The larger the coil and the larger the current, the greater will be the penetration of the inductive effect. As the induction is effective for only a few inches in an ordinary coil of 6 or 8 inches in length, the instrument is useful for minerals lying near the surface. It may be used to advantage on the sea bottom, along cliffs, in wells and borings, and upon ground abounding in metals lying near the surface, by simply causing it to pass over or near such surfaces. When it is to be used under water, it must of course be inclosed in a waterproof casing of non-metallic material.

This instrument, which is an induction coil pure and simple, should not be confounded with the induction balance described below.

The induction balance invented by Prof. D. E. Hughes has had a number of useful applications, one of which is the electric submarine detecter of Capt. McEvoy. Prof. Hughes demonstrated the extraordinary sensitiveness of the apparatus to the presence of small pieces of metal when brought near to one or other pair of coils.

The arrangement of the balance will be understood from Fig. 6, where $P\,S$ and $P^1\,S^1$ are the four coils of the balance, arranged in pairs separated from each other and connected by insulated wires. The coils, $P$ and $P^1$, are joined together through a battery, $B$, and a key or interrupter, $I$, thus constituting the "primary" circuit of the balance. The coils, $S\,S^1$, are connected through a telephone, $T$, and constitute the "secondary" circuit of the balance. The interrupter, $I$, may be either manipulated by hand or automatically, so as to give a continuous action. Whenever the primary circuit is closed by its means, a current traverses the primary coils, $P\,P^1$, and induces a corresponding current in the secondary coils, $S\,S^1$. This current is of course audible in the telephone, $T$, but by reversing one of the secondary coils, say $S^1$, the current induced by the primary coil, $P^1$, in the coil, $S^1$, is made to oppose the current induced by the other primary coil,

FIG. 4.—MINER'S COMPASS.

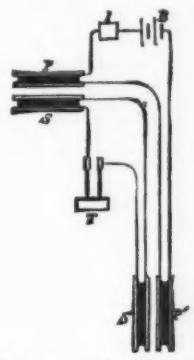


FIG. 6.—INDUCTION BALANCE.

$P$, in the other secondary coil, $S$, so that it is possible to cause these two induced currents to annul one another and produce silence in the telephone. This is done by making the two primary coils and also the two secondary coils alike in all respects, and placing the secondary, $S$, at the same distance from $P$ that $S^1$ is from $P^1$. The final adjustment to produce silence in the telephone can be made by altering the distance between a secondary coil and its primary, say the distance of $S$ from $P$, or it can be made by means of a small piece of metal adjusted near one pair of coils, as was originally shown by Prof. Hughes. To employ this arrangement for detecting metal masses it is only necessary to obtain a sufficiently good balance in this way, and explore the field where the metal is supposed to lie by moving about the pair of coils, $S^1\,P^1$. Then, if these coils come near a piece of metal, the inductive

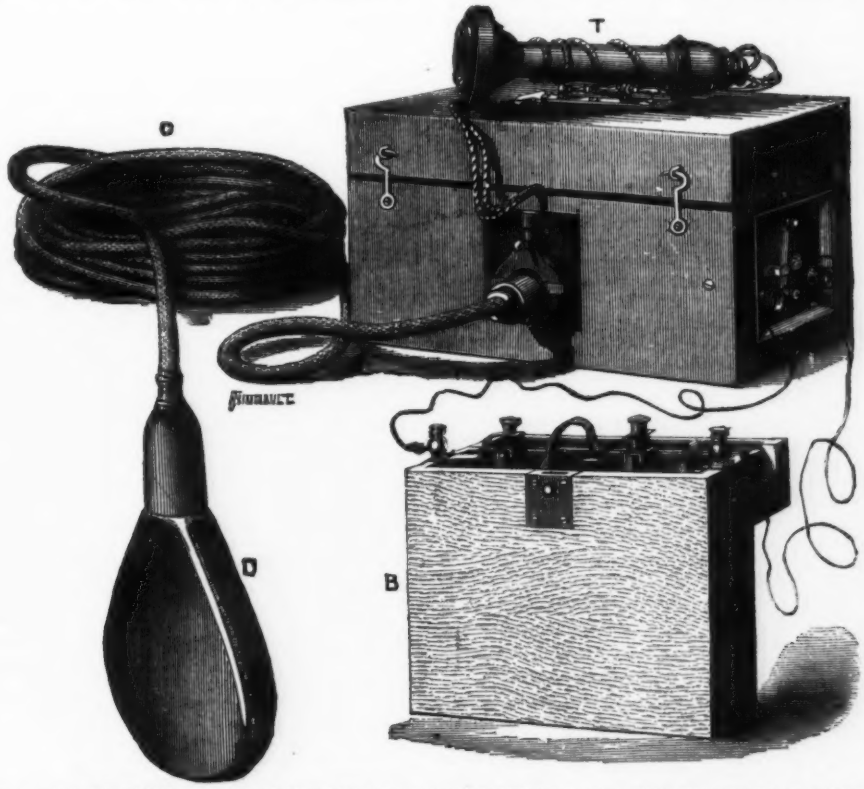



FIG. 7.—INSTRUMENT FOR DETECTING THE PRESENCE OF METALS UNDER WATER.

disturbance which its presence creates will upset the existing balance, and the telephone, before silent or nearly so, will give out distinctly audible sounds, owing to the predominance of the induced currents in the secondary, $S^1$, over those in the secondary, $S$.

The idea of applying the balance to the detection of metals has been worked out by Capt. McEvoy, who has reduced it to a thoroughly practical form. This actual apparatus is illustrated in Fig. 7, where *A* is a portable case containing the adjustable coils, *P S*, and the interrupter, *I*; *B* is a voltaic battery of two cells, which may be replaced by a small magneto-electric machine giving alternating currents; *T* is the telephone in the secondary circuit; *C* is an insulated cable conveying the wires connecting up the two pairs of coils; and *D* is the detecting or exploring case containing the two secondary coils, $S^1$ $P^1$. The coils, *P S*, inside the box, *A*, are separated by a layer of soft India rubber, and an ivory screw passes through both coils and the rubber washer between. An ebonite head to the screw is adjusted by hand so as to press the coils together or let them further apart by regulating the pressure between them and the India rubber. The simple device adjusts the balance of induction and reduces the telephone to silence.

The interrupter is a special device which consists of a small iron reed or tongue kept in vibration by a small double-poled electro-magnet, thereby interrupting the current a certain number of times per second, so as to give out a definite note which is easily recognizable in the telephone.

A switch, *E*, at the box turns the current from the battery on and off the interrupter at a moment's notice. The telephone is the ordinary speaking receiver of Bell.

The cable, *C*, is insulated with India rubber having its pores filled up with ozokerit or black earth wax forced in under pressure and when in a hot fluid state. It is further protected with an outer braided sheathing and is fitted to the box, *A*, by an ingenious socket, which in an instant establishes connection between the corresponding primaries and secondaries, and locks them together. The detecting case, *D*, is made of wood soaked with paraffin wax. It is water tight, and contains two exploring coils, *S P*., Fig. 6. When it is lowered into the water by the cable, *C*, and moved about, or dragged over the bottom, the instant it comes against a piece of metal, such as a torpedo case, a chain, or a submarine cable, it disturbs the balance, and the note, heard in the telephone very faintly until now, becomes unmistakably loud and clear. It is indeed somewhat surprising to find so marked an effect.

If there is any objection to this instrument, it is that a body of metal lying in the plane of the coil will not affect it.

## CONCRETE BUILDING BLOCKS.*

By S. B. NEWBERRY.

IN the industrial progress of this country there is no feature more remarkable and striking than the development which has taken place in the applications of Portland cement. Fifteen years ago the amount of Portland cement used for all purposes in the United States was about two and a half million barrels, of which four-fifths was imported from Europe. In 1905 the consumption exceeded thirty million barrels, a twelve-fold increase, and practically the whole of this is of American manufacture. The first and greatest victory won by the new material was its substitution for block stone in masonry constructions, such as piers, abutments, and foundations, and for flagstone in the laying of sidewalks. Then followed a multitude of lesser uses, such as sewer pipe, tiles, fence posts, curb and gutter, piles, and ornamental architectural work of every description. Reinforced with steel rods, cement concrete has come rapidly into use in the construction of complete buildings and bridges.

Having gained full recognition as a building material of the first rank in engineering and monumental architecture, Portland cement is now invading the field of dwelling construction. All but the more costly dwellings have, until recently, been built of wood, a material that has only the qualities of cheapness and convenience to recommend it, since frame structures are admittedly perishable, uncomfortable, and unsafe against fire. Lately, however, wood has lost even the quality of cheapness, and owing to the exhaustion of our forests has advanced fully fifty per cent in price. This has been a great hardship to home-seekers, and has forced builders to look for some other material for dwelling construction. Happily, Portland cement comes to the front, as usual, to fill the want. The hollow concrete building block, *properly made and used*, forms an ideal material for the exterior walls of buildings, and this replaces the part which, in wood, most rapidly deteriorates from exposure to weather. Buildings constructed of hollow concrete blocks are no higher in first cost than those built of frame, and are far less expensive in repairs. They have all the advantages of stone and brick in point of comfort, coolness in summer and warmth in winter, and in respect of beauty may at small cost be made fully equal to those of any other material.

Unfortunately, owing to poor workmanship and lack of artistic design, a large part of the hollow block buildings hitherto erected have fallen far short of the excellence above described. A multitude of men without capital and inexperienced in the use of cement have embarked in the business of block making, attracted by the glowing prospects of profits held out by the army of block machine agents. As a result, great quantities of inferior blocks, weak, porous, and unsound, have been and are being turned out, and have been erected by careless and unskilled builders into defective and ugly structures. This state of affairs is an injury to competent and conscientious block manufacturers, and an obstacle to the adoption of a most excellent and promising building material. Blocks of first-rate quality can easily and cheaply be made, with small outlay for machinery, provided certain simple rules are intelligently followed. It is the purpose of this paper to state briefly the causes of faults in concrete blocks, and the precautions by which good and reliable work may be assured.

### CONCRETE.

Concrete is an artificial stone consisting of coarse and fine fragments, such as sand, gravel, and broken stone, united by cement to a solid mass.

The strength of concrete depends greatly upon its density, and this is secured by using coarse material which contains the smallest amount of voids or empty spaces. Different kinds of sand, gravel, and stone vary greatly in the amount of voids they contain, and by judiciously mixing coarse and fine material the voids may be much reduced and the density increased. The density and percentage of voids in concrete material may be determined by filling a box of one cubic foot capacity and weighing it. One cubic foot of solid quartz or limestone, entirely free from voids, would weigh 165 pounds, and the amount by which a cubic foot of any loose material falls short of this weight represents the proportion of voids contained in it. For example, if a cubic foot of sand weighs 115½ pounds, the voids would be 49½-165ths of the total volume, or 30 per cent.

The following table gives the per cent of voids and weight per cubic foot of some common concrete materials:

| | Per cent Voids. | Wt. per cu. ft. |
|---|---|---|
| Sandusky Bay sand | 32.3 | 111.7 lb. |
| Same through 20-mesh screen | 38.5 | 101.5 lb. |
| Gravel, ¼ to ¼ inch | 42.4 | 95.0 lb. |
| Broken limestone, egg-size | 47.0 | 87.4 lb. |
| Limestone screenings, dust to ½ inch | 26.0 | 122.2 lb. |

It will be noted that screening the sand through a 20-mesh sieve, and thus taking out the coarse grains, considerably increased the voids and reduced the weight; thus decidedly injuring the sand for making concrete.

The following figures show how weight can be increased and voids reduced by mixing fine and coarse material:

| | Per cent Voids. | Wt. per cu. ft. |
|---|---|---|
| Pebbles, about 1 inch | 38.7 | 101.2 lb. |
| Sand, 30 to 40 mesh | 35.9 | 105.8 lb. |
| Pebbles plus 38.7 per cent sand, by vol. | 19.2 | 133.5 lb. |

Experiments have shown that the strength of concrete increases greatly with its density; in fact, a slight increase in weight per cubic foot adds very decidedly to the strength.

The gain in strength obtained by adding coarse material to mixtures of cement and sand is shown in the following table of results of experiments made in Germany by R. Dykerhoff. The blocks tested were 2½-inch cubes, 1 day in air and 27 days in water:

| Proportions by Measure. | | | Per Cent Cement. | Compression Strength. |
|---|---|---|---|---|
| Cement. | Sand. | Gravel. | By Volume. | Lbs. per Sq. In. |
| 1 | 2 | ... | 33.0 | 2,125 |
| 1 | 2 | 5 | 12.5 | 2,387 |
| 1 | 3 | ... | 25.0 | 1,383 |
| 1 | 3 | 6½ | 9.5 | 1,515 |
| 1 | 4 | ... | 20.0 | 1,063 |
| 1 | 4 | 8½ | 7.4 | 1,304 |

These figures show how greatly the strength is improved by adding coarse material, even though the proportion of cement is thereby reduced. A mixture of 1 to 12½ of properly-proportioned sand and gravel is, in fact, stronger than 1 to 4, and nearly as strong as 1 to 3, of cement and sand only.

In selecting materials for concrete, those should be chosen which give the greatest density. If it is practicable to mix two materials, as sand and gravel, the proportion which gives the greatest density should be determined by experiment, and rigidly adhered to in making concrete, whatever proportion of cement it is decided to use. Well proportioned dry sand and gravel or sand and broken stone, well shaken down, should weigh at least 125 pounds per cubic foot. Limestone screenings, owing to minute pores in the stone itself, are somewhat lighter, though giving equally strong concrete. They should weigh at least 120 pounds per cubic foot. If the weight is less, there is probably too much fine dust in the mixture.

The density and strength of concrete are also greatly improved by use of a liberal amount of water. Enough water must be used to make the concrete thoroughly soft and plastic, so as to quake strongly when rammed. If mixed too dry it will never harden properly, and will be light, porous, and crumbling.

Thorough mixing of concrete materials is essential, to increase the density and give the cement used a chance to produce its full strength. The cement, sand, and gravel should be intimately mixed dry, then the water added and the mixing continued. If stone or coarse gravel is added, this should be well wetted and thoroughly mixed with the mortar.

### MATERIALS FOR CONCRETE BUILDING BLOCKS.

In the making of building blocks the spaces to be filled with concrete are generally too narrow to permit the use of very coarse material, and the block-maker is limited to gravel or stone not exceeding ½ or ¼ inch in size. A considerable proportion of coarse material is, however, just as necessary as in other kinds of concrete work, and gravel or screenings should be chosen which will give the greatest possible density. For good results, at least one-third of the material, by weight, should be coarser than ⅛ inch. Blocks made from such gravel or screenings, 1 to 5, will be found as good as 1 to 3 with sand only. It is a mistake to suppose that the coarse fragments will show on the surface; if the mixing is thorough this will not be the case. A moderate degree of roughness or variety in the surface of blocks is, in fact, desirable, and would go far to overcome the prejudice which many architects hold against the smooth, lifeless surface of cement work.

Sand and gravel are, in most cases, the cheapest material to use for block work. The presence of a small per cent of clay or loam is not harmful provided the mixing is thorough.

Stone screenings, if of good quality, give fully as strong concrete as sand and gravel, and usually yield blocks of somewhat lighter color. Screenings from soft stone should be avoided, also such as contain too much dust. This can be determined from the weight per cubic foot, and by a sifting test. If more than two-thirds pass ¼-inch, and the weight (well jarred down) is less than 120 pounds, the material is not the best.

Cinders are sometimes used for block work; they vary greatly in quality, but if clean and of medium coarseness will give fair results. Cinder concrete never develops great strength, owing to the porous character and crushability of the cinders themselves. Cinder blocks may, however, be strong enough for many purposes, and suitable for work in which great strength is not required.

Lime.—It is well known that slaked lime is a valuable addition to cement mortar, especially for use in air. In sand mixtures, 1 to 4 or 1 to 5, at least one-third of the cement may be replaced by slaked lime without loss of strength. The most convenient form of lime for use in block-making is the dry-slaked or hydrate lime, now a common article of commerce. This is, however, about as expensive as Portland cement, and there is no great saving in its use. Added to block concrete, in the proportion of ¼ to ½ the cement used, it will be found to make the blocks lighter in color, denser, and decidedly less permeable by water.

Cement.—Portland cement, to-day, is the only hydraulic material to be seriously considered by the block-maker, and at present prices there is nothing gained by attempting the use of any of the cheaper substitutes. Natural and slag cements and hydraulic lime are useful for work which remains constantly wet, but greatly inferior in strength and durability when exposed to dry air. A further advantage of Portland cement is the promptness with which it hardens and develops its full strength; this quality alone is sufficient to put all other cements out of consideration for block work.

### PROPORTIONS.

There are three important considerations which must be kept in view in adjusting the proportions of materials for block concrete—strength, permeability, and cost.

So far as strength goes, it may easily be shown that concretes very poor in cement, as 1 to 8 or 1 to 10, will have a crushing resistance far beyond any load that they may be called upon to sustain. Such concretes are, however, extremely porous, and absorb water like a sponge. It is necessary, also, that the blocks shall bear a certain amount of rough handling at the factory and while being carted to work and set up in the wall, and safety in this respect calls for a much greater degree of hardness than would be needed to bear the weight of the building. Again, strength and hardness, with a given proportion of cement, depend greatly on the character of the other materials used; blocks made of cement and sand, 1 to 3, will not be so strong or so impermeable to water as those made from a good mixed sand and gravel, 1 to 5. On the whole, it is doubtful whether blocks of satisfactory quality can be made, by hand mixing and tamping, under ordinary factory conditions, from a poorer mixture than 1 to 5. Even this proportion requires for good results the use of properly-graded sand and gravel or screenings, a liberal amount of water, and thorough mixing and tamping. When suitable gravel is not obtainable, and coarse mixed sand only is used, the proportion should not be less than 1 to 4. Fine sand alone is a very bad material, and good blocks cannot be made from it except by the use of an amount of cement which would make the cost very high.

The mixtures above recommended, 1 to 4 and 1 to 5, will necessarily be somewhat porous, and may be decidedly so if the gravel or screenings used is not properly graded. The water-resisting qualities may be greatly improved, without loss of strength, by replacing a part of the cement by hydrate lime. This is a light, extremely fine material, and a given weight of it goes much further than the same amount of cement in filling the pores of the concrete. It has also the effect of making the wet mixture more plastic and

* Reprint of a monograph issued by the Association of American Portland Cement Manufacturers.

more easily compacted by ramming, and gives the finished blocks a lighter color.

The following mixtures, then, are to be recommended for concrete blocks. By "gravel" is meant a suitable mixture of sand and gravel, or stone screenings, containing grains of all sizes, from fine to ½ inch.

1 to 4 Mixtures, by Weight.

Cement 150, gravel 600.
Cement 125, hyd. lime 25, gravel 600.
Cement 100, hyd. lime 50, gravel 600.

1 to 5 Mixtures, by Weight.

Cement 120, gravel 600.
Cement 100, hyd. lime 20, gravel 600.

Proportion of Water.—This is a matter of the utmost consequence, and has more effect on the quality of the work than is generally supposed. Blocks made from too dry concrete will always remain soft and weak, no matter how thoroughly sprinkled afterward. On the other hand, if blocks are to be removed from the machine as soon as made, too much water will cause them to stick to the plates and sag out of shape. It is perfectly possible, however, to give the concrete enough water for maximum density and first-class hardening properties, and still to remove the blocks at once from the mold. A good proportion of coarse material allows the mixture to be made wetter without sticking or sagging. Use of plenty of water vastly improves the strength, hardness and waterproof qualities of blocks, and makes them decidedly lighter in color. The rule should be:

Use as much water as possible without causing the blocks to stick to the plates or to sag out of shape on removing from the machine.

The amount of water required to produce this result varies with the materials used, but is generally from 8 to 9 per cent of the weight of the dry mixture. A practised block-maker can judge closely when the right amount of water has been added, by squeezing some of the mixture in the hand. Very slight variations in proportion of water make such a marked difference in the quality and color of the blocks that the water, when the proper quantity for the materials used has been determined, should always be accurately measured out for each batch. In this way much time is saved and uncertainty avoided.

Facing.—Some block-makers put on a facing of richer and finer mixture, making the body of the block of poorer and coarser material. As will be explained later, the advantage of the practice is, in most cases, questionable, but facings may serve a good purpose in case a colored or specially water-proof surface is required. Facings are generally made of cement and sand or fine screenings, passing a ¼-inch sieve. To get the same hardness and strength as a 1 to 5 gravel mixture, at least as rich a facing as 1 to 3 will be found necessary. Probably 1 to 2 will be found better, and if one-third the cement be replaced by hydrate lime the waterproof qualities and appearance of the blocks will be improved. A richer facing than 1 to 2 is liable to show greater shrinkage than the body of the block, and to adhere imperfectly or develop hair-cracks in consequence.

Poured Work.—The above suggestions on the question of proportions of cement, sand, and gravel for tamped blocks apply equally to concrete made very wet, poured into the mold, and allowed to harden a day or longer before removing. Castings in a sand mold are made by the use of very liquid concrete; sand and gravel settle out too rapidly from such thin mixtures, and rather fine limestone screenings are generally used.

MIXING.

To get the full benefit of the cement used it is necessary that all the materials shall be very thoroughly mixed together. The strength of the block as a whole will be only as great as that of its weakest part, and it is the height of folly, after putting a liberal measure of cement, to so slight the mixing as to get no better result than half as much cement, properly mixed, would have given. The poor, shoddy, and crumbly blocks turned out by many small-scale makers owe their faults chiefly to careless mixing and use of too little water, rather than to too small proportion of cement.

The materials should be mixed, dry, until the cement is uniformly distributed and perfectly mingled with the sand and gravel or screenings; then the water is to be added and the mixing continued until all parts of the mass are equally moist and every particle is coated with the cement paste.

Concrete Mixers.—Hand-mixing is always imperfect, laborious, and slow, and it is impossible by this method to secure the thorough stirring and kneading action which a good mixing machine gives. If a machine taking 5 or 10 horse-power requires five minutes to mix one-third of a yard of concrete, it is of course absurd to expect that two men will do the same work by hand in the same time. And the machine never gets tired or shirks if not constantly urged, as it is the nature of men to do. It is hard to see how the manufacture of concrete blocks can be successfully carried on without a concrete mixer. Even for a small business it will pay well in economy of labor and excellence of work to install such a machine, which may be driven by a small electric motor or gasoline engine. In work necessarily so exact as this, requiring perfectly uniform mixtures and use of a constant percentage of water, *batch mixers*, which take a measured quantity of material, mix it, and discharge it, at each operation, are the only satisfactory type, and continuous mixers are unsuitable. Those of the pug-mill type, consisting of an open trough with revolving paddles and bottom discharge, are positive and thorough in their action, and permit the whole operation to be watched and controlled. They should be provided with extensible arms of chilled iron, which can be lengthened as the ends become worn.

SYSTEMS OF CONCRETE CONSTRUCTION.

Solid or Monolithic Walls.—Foundations, walls, and complete buildings of solid concrete have been erected in great numbers since the days of the Romans, and in modern times the use of reinforced or armored concrete has adapted this type of construction to a great variety of uses. In this class of work, walls, cornices, and ornamental details of buildings are molded in place, by the use of special forms held in position by various mechanical devices. This is necessarily somewhat expensive, and requires a high degree of skill on the part of the builder; it can be successfully done only by contractors who make a specialty of the process and are provided with all necessary appliances.

Concrete Block Systems.—For smaller and less costly buildings, *separate blocks*, made at the factory and built up into the walls in the same manner as brick or blocks of stone, are simpler, less expensive, and much more rapid in construction than monolithic work. They also avoid some of the faults to which solid concrete work, unless skillfully done, is subject, such as the formation of shrinkage cracks.

There are two systems of block making, differing in the consistency of the concrete used:

1. Blocks tamped or pressed from semi-wet concrete, and removed at once from the mold.

2. Blocks poured or tamped from wet concrete, and allowed to remain in the mold until hardened.

Tamped Blocks from Semi-Wet Mixture.—These are practically always made on a block-machine, so arranged that as soon as a block is formed the cores and side-plates are removed and the block lifted from the machine. By far the larger part of the blocks on the market are made in this way. Usually these are of the *one-piece* type, in which a single block, provided with hollow cores, makes the whole thickness of the wall. Another plan is the *two-piece* system, in which the face and back of the wall are made up of different blocks, so lapping over each other as to give a bond and hold the wall together. Blocks of the two-piece type are generally formed in a hand or hydraulic press.

Various shapes and sizes of blocks are commonly made; the builders of the most popular machines have, however, adopted the standard length of 32 inches and height of 9 inches for the full-sized block, with thickness of 8, 10, and 12 inches. Lengths of 24, 16, and 8 inches are also obtained on the same machines by the use of parting plates and suitably divided faceplates; any intermediate lengths and any desired heights may be produced by simple adjustments or blocking off.

Blocks are commonly made plain, rock-faced, tool-faced, paneled, and of various ornamental patterns. New designs of faceplates are constantly being added by the most progressive machine makers.

Block Machines.—There are many good machines on the market, most of which are of the same general type, and differ only in mechanical details. They may be divided into two classes: those with vertical and those with horizontal face. In the former the face-plate stands vertically, and the block is simply lifted from the machine on its base plate as soon as tamped. In the other type the faceplate forms the bottom of the mold; the cores are withdrawn horizontally, and by the motion of a lever the block with its face-plate is tipped up into a vertical position for removal. In case it is desired to put a facing on the blocks, machines of the horizontal-face type are considered the more convenient, though a facing may easily be put on with the vertical-face machine by the use of a parting plate.

Blocks Poured from Wet Concrete.—As already stated, concrete made too dry is practically worthless, and an excess of water is better than a deficiency. The above-described machine process, in which blocks are tamped from damp concrete and at once removed, gives blocks of admirable hardness and quality if the maximum of water is used. A method of making blocks from very wet concrete, by the use of a large number of separable molds of sheet steel, into which the wet concrete is poured and in which the blocks are left to harden for 24 hours or longer, has come into considerable use. By this method blocks of excellent hardening and resistance to water are certainly obtained. Whether the process is the equal of the ordinary machine method in respect of economy and beauty of product must be left to the decision of those who have had actual experience with it.

The well-known cast-stone process consists in pouring liquid concrete mixture into a sand mold made from a pattern in a manner similar to that in which molds for iron castings are produced. The sand absorbs the surplus water from the liquid mixture, and the casting is left in the mold for 24 hours or longer until thoroughly set. This process necessitates the making of a new sand mold for every casting, and is necessarily much less rapid than the machine method. It is less extensively used for building blocks than for special ornamental architectural work, sills, lintels, columns, capitals, etc., and for purposes of this kind it turns out products of the highest quality and beauty.

Tamping of Concrete Blocks.—This is generally done by means of hand-rammers. Pneumatic tampers, operated by an air-compressor, are in use at a few plants, apparently with considerable saving in time and labor and improvements in quality of work. Molding concrete by *pressure*, either mechanical or hydraulic, is not successful unless the pressure is applied to the face of a comparatively thin layer. If compression of thick layers, especially of small width, is attempted, the materials arch and are not compacted at any considerable depth from the surface. Molding blocks by pressure is therefore practised only in the two-piece system, in which the load is applied to the surface of pieces of no great thickness. Hand tamping must be conscientious and thorough, or poor work will result. It is important that the mold should be filled a little at a time, tamping after each addition; at least four fillings and tampings should be given to each block. If the mixture is wet enough no noticeable layers will be formed by this process.

Hardening and Storage.—Triple decked cars to receive the blocks from the machines will be found a great saving of labor, and are essential in factories of considerable size. Blocks will generally require to be left on the plates for at least 24 hours, and must then be kept under roof, in a well-warmed room, with frequent sprinkling, for not less than five days more. They may then be piled up out of doors, and in dry weather should be wetted daily with a hose. Alternate wetting and drying is especially favorable for the hardening of cement, and concrete so treated gains much greater strength than if kept continuously in water or dry air.

Blocks should not be used in building until at least four weeks from the time they are made. During this period of seasoning, blocks will be found to shrink at least 1-16 inch in length, and if built up in a wall when freshly made, shrinkage cracks in the joints or across the blocks will surely appear.

Efflorescence, or the appearance of a white coating on the surfaces, sometimes takes place when blocks are repeatedly saturated with water and then dried out; blocks laid on the ground are more liable to show this defect. It results from diffusion of soluble sulphates of lime and alkalies to the surface. It tends to disappear in time, and rarely is sufficient in amount to cause any complaint.

PROPERTIES OF CONCRETE BLOCKS.

Strength.

In the use of concrete blocks for the walls of buildings, the stress to which they are subjected is almost entirely one of *compression*. In compressive strength well-made concrete does not differ greatly from ordinary building stone. It is difficult to find reliable records of tests of sand and gravel concrete, 1 to 4 and 1 to 5, such as is used in making blocks; the following figures show strength of concrete of approximately this richness, also the average of several samples each of well-known building stones, as stated by the authorities named:

Limestone, Bedford, Ind. (Ind. Geo. Survey)...7792 lb.
Limestone, Marblehead, Ohio (Q. A. Gillmore).7393 lb.
Sandstone, N. Amherst, Ohio (Q. A. Gillmore)..5831 lb.
Gravel concrete, 1:1.6:2.8, at 1 yr. (Candlot)..5500 lb.
Gravel concrete, 1:1.6:3.7, at 1 yr. (Candlot)...5050 lb.
Stone concrete, 1:2:4 at 1 yr. (Boston El. R.R.).3904 lb.

Actual tests of compression strength of hollow concrete blocks are difficult to make, because it is almost impossible to apply the load uniformly over the whole surface, and also because a block 16 inches long and 8 inches wide will bear a load of 150,000 to 200,000 pounds, or more than the capacity of any but the largest testing machines. Three one-quarter blocks, 8 inches long, 8 inches wide, and 9 inches high, with hollow space equal to one-third of the surface, tested at the Case School of Science, showed strengths of 1,805, 2,000, and 1,530 pounds per square inch, respectively, when 10 weeks old.

Two blocks 6 x 8 x 9 inches, 22 months old, showed crushing strength of 2,530 and 2,610 pounds per square inch.

These blocks were made of cement 1¼, lime ½, sand and gravel 6, and were tamped from damp mixture.

It is probably safe to assume that the minimum crushing strength of well-made blocks, 1 to 5, is 1,000 pounds per square inch at 1 month and 2,000 pounds at 1 year.

Now a block 12 inches wide and 24 inches long has a total surface of 288 square inches, or, deducting 1-3 for openings, a net area of 192 inches. Such a block, 9 inches high, weighs 130 pounds. Assuming a strength of 1,000 pounds and a factor of safety of 5, the safe load would be 200 pounds per square inch, or 200 × 192 = 38,400 pounds for the whole surface of the block. Dividing this by the weight of the block, 130 pounds, we find that 295 such blocks could be placed one upon another, making a total height of wall of 222 feet, and still the pressure on the lowest block would be less than one-fifth of what it would actually bear.

This shows how greatly the strength of concrete blocks exceeds any demands that are ever made upon it in ordinary building construction.

The safe load above assumed, 200 pounds, seems low enough to guard against any possible failure. In Taylor and Thompson's work on concrete a safe load of 450 pounds for concrete 1 to 2 to 4 is recommended; this allows a factor of safety of 5½. On the other hand, the Building Code of the city of Cleveland permits concrete to be loaded only to 150 pounds per square inch, and limits the height of walls of 12-inch blocks to 44 feet. The pressure of such a wall would be only 40 pounds per square inch; adding the weight of two floors at 25 pounds per square foot each, and roof with snow and wind pressure, 40 pounds per square foot, we find that with a span of 25 feet the total weight on the lowest blocks would be only 52 pounds per square inch, or about one-twentieth of their minimum compression strength.

Blocks with openings equal to only one-third the surface, as required in many city regulations, are

heavy to handle, especially for walls 12 inches and more in thickness, and, as the above figures show, are enormously stronger than there is any need of. Blocks with openings of 50 per cent would be far more acceptable to the building trade, and if used in walls not over 44 feet high, with floors and roof calculated as above for 25 feet span, would be loaded only to 56 pounds per square inch of actual surface. This would give a factor of safety of 18, assuming a minimum compression strength of 1,000 pounds.

There is no doubt that blocks with one-third opening are inconveniently and unnecessarily heavy. Such a block, 32 inches long, 12 inches wide, and 9 inches high, has walls about 3½ inches thick, and weighs 180 pounds. A block with 50 per cent open space would have walls and partitions 2 inches in thickness, and would weigh about 130 pounds. With proper care in manufacture, especially by using as much water as possible, blocks with this thickness of walls may be made thoroughly strong, sound and durable. It is certainly better for strength and water-resisting qualities to make thin-walled blocks of rich mixture, rather than heavy blocks of poor and porous material.

(To be continued.)

[Continued from SUPPLEMENT No. 1567, page 25106.]

## ARMORED CONCRETE.—II.*

By Lieut. HENRY J. JONES, A.O.D., A.R.C.Sc. (Lond.), Inspector of Ordnance Machinery.

BEFORE discussing the systems and methods of design used in connection with armored concrete, it is obvious that a statement must be made concerning the properties of the materials which we propose to use.

Steel is so common and familiar as to need no description; nevertheless it is to be remembered that, in the absence of experimental evidence, we are ignorant as to how the properties of steel may be modified by its being embedded in concrete. What is the effect of this on the elastic properties of steel? How is the initial state of the steel affected by subsequent shrinkage of the concrete? These are questions which experiment, and experiment alone, can answer; in the meantime we must use a large "factor of ignorance" to cover eventualities. So far as we are immediately concerned, the only fact of importance is, that the adhesion between steel and the concrete which has set round it varies from 550 to 680 pounds per square

FIG. 1.—HENNEBIQUE STIRRUP.

inch; and as this is above the safe compressive stress for the concrete, we are justified in assuming that failure will not occur through slip between the steel and the concrete. Even were this coefficient of adhesion in dispute, it would be sufficient to know that experiments have repeatedly shown that armored concrete beams admit of distortion and ultimate fracture without the continuity of metal and concrete being destroyed. The steel should be of the best quality, and capable of being worked to 7½ tons per square inch.

The sections of the steel employed vary in different systems, being round, flat, square, angle, and tee. In all cases the simplest section is the best, as it costs less, and readily allows the concrete to be rammed into the closest contact with the entire surface of the armoring. Small sections are better than large ones, as by their use we can get a more uniform distribution of stress in the steel; we can also readily bend and work them into any required shape; and finally, the most economical disposition of material is obtained, the metal being placed at the maximum distance from the neutral axis. Care should always be taken that there is a good protective covering of concrete external

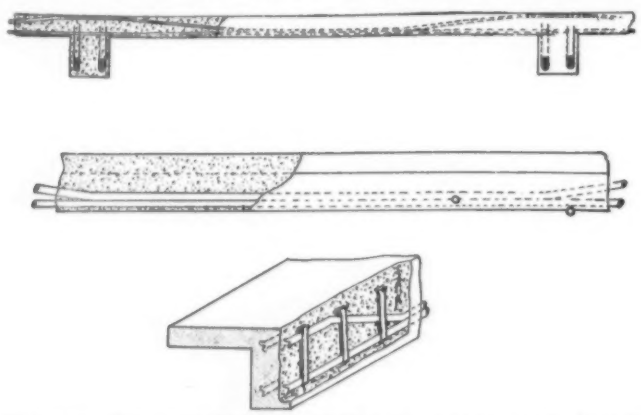


FIG. 2.—RODS AND STIRRUPS APPLIED TO FLOOR AND GIRDERS.

to the armoring; the thickness of this covering should never be less than from one to two inches.

Expanded metal meshing is being increasingly employed, more particularly in the lighter forms of construction. It consists of sheets of metal which have been mechanically slit and expanded, so as to produce a network. This type of armoring has many and obvious advantages. Its mere existence is proof of good steel, and it forms an excellent key to likenesses of concrete too thin to allow of the armoring being in the form of rods; thus it is very useful for concrete plaster, ceiling, and partition wall work. The overlapping

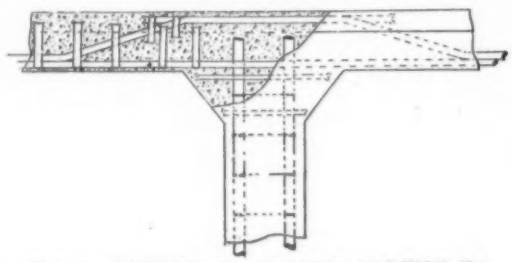


FIG. 3.—METHOD OF JOINING COLUMN TO FLOOR.

of two sheets of metal for a few inches, before the concrete is laid, is sufficient to securely unite them; and the arrangement of armoring in sheets secures the great advantage of longitudinal and transverse strength, which greatly increases the adhesion and strengthens the concrete against shear.

Concrete has long had the reputation of being erratic in its behavior, but strict inquiry into the cause of its many failures has revealed these to be due to

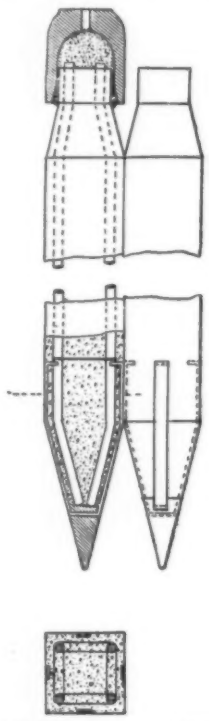


FIG. 4.—ARMORING FOR A 12-INCH x 12-INCH KING PILE.

bad workmanship or inferior materials. In some cases the aggregate was either too large or too small, or was composed of flinty materials which fractured under the slightest provocation; in cases where care had been taken to secure a suitable aggregate, it was used either in an unclean state, or had too much or too little water added in the mixing. But by far the greatest number of failures have been due to the inferior quality of the cement. The use of unsuitable cement must be attributed either to laxity in its testing, or faultiness in the specification under which it was supplied.

Good cement is absolutely necessary for armored concrete. At present we can get English Portland cement, which will leave no residue on a 76 x 76 sieve, wire 0.005 inch diameter, and only 10 per cent on a 180 x 180 sieve, wire 0.0025 inch diameter. In any case, it should be specified to leave no more than 5 per cent on a 120 x 120 sieve, wire 0.0035 inch diameter. Slow-setting cement is best; pats made with the minimum amount of water should set in not less than five hours when the temperature is 35 deg. F., and not less than twenty minutes at 75 deg. F. The aggregate, when used for floors, columns, walls, etc., should all pass through a ¾-inch ring, and a one-inch ring for footings; it should be quite clean, the proportions of sand and stone being adjusted to give a concrete quite full. The concrete should always be used in small quantities, so that after rolling or ramming no porosity may be possible. The sand should be clean and sharp, free from loam and all other impurities, the grains varying from ¼ inch down to the smallest size obtainable at a reasonable cost. The proportions of cement, sand, and stone should not be less than 1:2:4 for columns and girders; and 1:2½:5 for walls, floors, and footings.

The best plan is to do the mixing and laying as rapidly as possible; if the concrete is made moderately wet, the ramming should be continued until water appears at the surface. When the concrete has been laid and rammed to the specified dimensions, the shuttering should not be disturbed for at least three or four weeks, depending on the temperature. In all cases the shuttering must be well braced and supported, so as to guard against undue deflection when the concrete is deposited. To give a good finish to the work, the shuttering should be quite true to the required shape, and have the working faces planed smooth and covered with soap or grease, so as to prevent sticking. After the concrete has set and the shuttering has been removed, at least 5 per cent of the girders should be tested with a load 50 per cent above the maximum working load, and the maximum deflection should not be more than from 1-800 to 1-600 of the span. Piles should be left in their forms at least four weeks before use, and longer if possible.

The safe compressive stress of concrete depends upon the quality and quantity of the cement, the nature

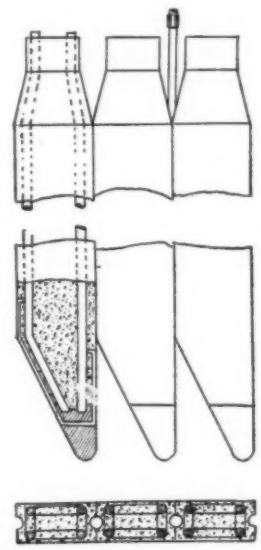


FIG. 5.—ARMORING FOR A 12-INCH x 6-INCH SHEET PILE.

and size of the aggregate, and particularly upon the skill exercised in the manufacture, and care in the use of the concrete. It is interesting to note that the compressive strength of concrete increases with age. Experience indicates that for piles, arches, walls, foundations, etc., which are subject to direct pressure, we may assume a safe working stress between 350 and 550 pounds per square inch. For beams, floor slabs, roofs, etc., 450 to 650 pounds per square inch may be taken. Concrete has little strength in tension or in shear; if necessary, we may safely assume the former to be from 30 to 60 and the latter from 20 to 30 pounds to the square inch. In carrying out calculations, it is usual to neglect both the tensile and shear strength in the most approved designs; provision is afterward made to take tensile and shear stresses by a suitable disposition of rods and stirrups. In the Hennebique system stirrups are used, as indicated in Fig. 1; these are spaced from four to twelve-inch centers along the rods, being closest where the shearing forces are most intense. Fig. 2 shows the arrangement of these stirrups in cross girders and floors. The necessity for these stirrups is provided by the fact that concrete ribs do not show the first signs of failure at their midpoints, where the tensile stresses are a maximum, but nearer the supports; the failure of the rib is indicated by diagonal cracks which arise from the combined action of the tensile and shearing stresses.

### COLUMNS AND PILES.

Armored concrete columns are made with either square, rectangular, or circular sections; when well-proportioned, the height of a column should not exceed fifteen times the diameter of its equivalent circular section. They are armored with from four to twenty rods, the diameters of which vary from ⅜ to 2½ inches.

The rods are placed as near as practicable to the circumference of the column, so as to give the greatest radius of gyration for the section; but, as stated above, they should never be placed so near the surface that

* Technics.

they have not at least one or two inches protective covering. The steel so disposed is able to take up the tensile stresses which may be induced in the column by eccentric loading, lateral shock, wind pressure, and the pull of belting.

The following table gives the maximum load which square columns will carry when the height does not exceed fifteen diameters. The percentage of steel exposed in cross section is never above 5 per cent, and is usually about 2½ per cent.

| Section of Column in Inches. | Safe Load in Tons. | Section of Column in Inches. | Safe Load in Tons. |
|---|---|---|---|
| 8 × 8 | 40 | 24 × 24 | 380 |
| 10 × 10 | 63 | 26 × 26 | 450 |
| 12 × 12 | 96 | 28 × 28 | 525 |
| 14 × 14 | 130 | 30 × 30 | 605 |
| 16 × 16 | 170 | 32 × 32 | 670 |
| 18 × 18 | 215 | 34 × 34 | 745 |
| 20 × 20 | 270 | 36 × 36 | 800 |
| 22 × 22 | 320 | 38 × 38 | 900 |

Columns and piles are made in wooden boxes, each consisting of three permanent sides and a fourth side which is temporary and removable. Under the patent rights of François Hennebique the armoring is placed in these boxes, and adjusted by gages to be within one or two inches of the sides. The concrete is laid and rammed, about six inches at a time, with small hand rammers. The open side of the box is built up by battens fitting into grooves in the permanent sides, as the work proceeds; this enables inspection of the work to be made, and facilitates the placing of the ties at the proper positions.

The ties are made of round wire 3-16 inch diameter, and are dropped down over the top of the steel rods. They are spaced from two-inch centers at the bottom and top, to twelve-inch centers in the center of length of the column, and are intended to prevent the steel rods from spreading out under the action of longitudinal loads. Fig. 3 shows the method of joining columns to the floor.

The Considere columns are very interesting. They are built on the same principle as wire guns, and consist of a circular concrete core wound with spirals of steel wire, the pitch of which is from one-seventh to one-tenth the diameter of the core. The whole is then covered with a layer of concrete, about two inches in thickness. These columns of Considere, when without longitudinal armoring, have an ultimate resistance of from 12,000 to 15,000 pounds per square inch, and if longitudinal armoring be introduced as well, we may safely work them to 6,000 pounds per square inch. These columns are very suitable for heavy loads, but are somewhat costly; for light loads the ordinary columns are preferable. It is a well-known fact that on setting in air, concrete shrinks; hence, when using longitudinal armoring, the concrete adhering to the steel is put in tension and the steel in compression. This action may be very severe, so much so that the elastic limit of the materials may have been reached even before the load comes on. In the case of spiral armoring, however, the shrinking of the concrete puts the steel in compression; when the load comes on, the spirals, tending to expand, are put in tension, and a state of molecular equilibrium is reached when the compressive stresses induced by the shrinking of the concrete are just neutralized by the tensile stresses induced by the loading. Afterward we have the whole tensile strength of the armoring available for any increased tensile stress induced by additional loading.

Piles are usually made in vertical molds, but are equally good when made horizontally. They constitute quite a unique feature of armored concrete construction, proving beyond all possible doubt that such a system is able to stand repeated shock without disintegration or dissociation of the steel and concrete. The pile carries a shoe with a chilled cast-iron point, and side plates of wrought iron to lock it to the concrete. The head of the pile is reduced in width to give a clearance, between adjacent piles, for the driving cap. This cap is of cast steel; it fits loosely over the head of the pile, being filled with sand or sawdust, and closed at its lower end by a clay ring held by a plug of yarn. This arrangement insures a very uniform blow being given to the pile head; it also allows the armoring to project beyond the concrete, to be connected to other parts of the structure, or to be bent into hook shape for convenience of handling. A section and elevation of a 12 x 12 pile is shown in Fig. 4.

Sheet piles are strengthened by rods clamped and cross-tied. They carry cast-iron shoes and wrought-iron locking straps, the heads being reduced to receive a driving cap. A projection is often cast on one pile to work in a groove cast in another. This insures a straight drive, and a good joint between successive piles. A special arrangement is sometimes used; an iron pipe is made to fit into a groove in the pile last driven, and another in the pile which is being driven; this pipe is connected to a powerful water pump, and not only serves to guide the piles, but also delivers water at a high pressure, which forces out the mud and sand, and prevents the jamming of the piles. When the piles are driven, the pipe is withdrawn and cement is run into the open groove, which, on setting, forms a very perfect joint. Fig. 5 shows the arrangement of armoring in sheet piles.

Piles up to 60 feet in length are now in use. The requisite cross-sectional area depends on the load to be carried and the nature of the site. The metal exposed in cross-section varies from 2 to 5 per cent, and is invariably of round rods, clamped, and tied as in the columns.

The following table gives particulars of Hennebique piles made and used at Southampton:

| Section of Pile in Inches. | Armouring. | Percentage of Steel in Cross-Section. |
|---|---|---|
| 12 × 12 | 4 rods 1¼ inches diam. | 5 |
| 14 × 14 | " 1½ " " | 2½ |
| 15 × 15 | " 1⅜ " " | 2½ |
| 16 × 12 | " 1¼ " " | 4½ |

(To be continued.)

## ON THE ELECTRIC CONDUCTIVITY OF A VACUUM.*

By J. A. FLEMING, M.A., D.Sc., F.R.S.

IN the thirteenth series of his Experimental Researches on Electricity, Faraday discusses the question whether a vacuum should be considered to be a conductor or a non-conductor of electricity. The subject may seem, to some people, to be of purely academic interest, and devoid of any technical value. Since, however, any increase in knowledge concerning the manner in which electricity is moved from place to place, and its relation to atoms of matter, is extremely practical, the consideration of the conductivity of a so-called vacuum is not an unimportant matter. Since the time of Faraday we have been able to make vacua far more complete than any attained by him. Nevertheless, any vacuum we can make can only be so called by courtesy. In air at ordinary pressure there are about $10^{20}$ molecules per cubic centimeter; hence, even if we can take out from any space all but one hundred-millionth of the original gas at atmospheric pressure, the molecular population of that space must still be very large. Sir James Dewar has shown that extremely high vacua can be most rapidly produced by condensing the residual air in an ordinary vacuum by cocoanut charcoal, cooled by liquid hydrogen, and it may be possible in this way to remove from any space all but a very small proportion of the gaseous matter present.

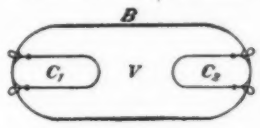



FIG. 1.

*B.* Bulb containing high vacuum. $C_1$, $C_2$. Carbon filaments sealed in, like an incandescent lamp.

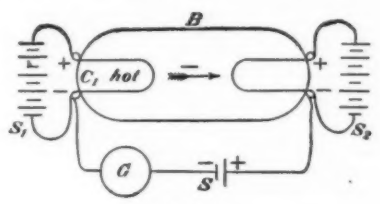



FIG. 2.

*B.* Vacuum bulb. $C_1$. Carbon filament to be rendered incandescent by insulated battery $S_1$. *G.* Galvanometer. *S.* A single cell sending negative electricity from hot filament to the cold one.

Let us assume that we make a high vacuum of one hundred-millionth of an atmosphere in a glass vessel, and that in it are placed two metal plates, say of platinum, at a distance of a millimeter apart. Let these plates be connected to platinum wires sealed through the glass. If the plates are cold, it is then possible to create between them a difference of potential of 100,000 volts or so, and yet not cause any discharge or the slightest measurable current across the space. A vacuum can be made such that an induction coil giving a spark of several centimeters length in air will not strike across a space of one millimeter in the vacuum between cold metal terminals. This fact at first sight appears to show that a high vacuum is a very perfect non-conductor, and this opinion has generally been held.

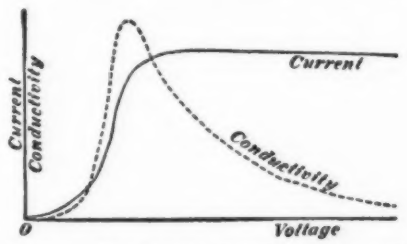



Fig. 3.—Curve Showing the Variation of Current and Conductivity through the Vacuum Valve, with Increasing Potential Difference between the Electrodes.

If, however, we modify the experiment slightly, we shall be able to show that the highest vacuum we can produce may, under other conditions, be a very good conductor.

Imagine a bulb of glass, made as in Fig. 1, containing two loops of platinum wire, or better still, two carbon filaments. Let this bulb be exhausted as completely as possible, so that in it the highest attainable vacuum is made. To achieve this, the filaments must be heated to bright incandescence while the exhaustion is going on. Having done this, if the secondary terminals of an induction coil are connected to the two separate filaments when cold, no discharge will take place across the vacuum between them, thus apparently showing that the space is a very perfect non-conductor. Suppose, however, that we render one or both of these filaments incandescent by passing electric currents through them by means of two insulated batteries of secondary cells, $S^1$, $S^2$ (Fig. 2), it will be found, on connecting a sensitive galvanometer, *G*, and a single cell, *S*, as a shunt to the two negative terminals of the two separate filaments, that a current of several milliamperes will pass across the vacuum under the electromotive force of this single cell. The arrangements should be as shown in Fig. 2. If only one of the filaments is ignited, and if it is that in connection with the negative terminal of the single cell in the shunt circuit, then the current still passes; but if the other filament alone is ignited, no current, or only

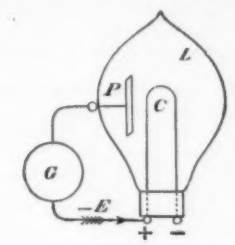



FIG. 4.

*L.* An ordinary carbon filament incandescent lamp. *C.* The carbon filament, rendered incandescent by a continuous current. *P.* A metal plate, sealed through the glass. *G.* Galvanometer through which flow negative electrons from the plate *P* when the other terminal of the galvanometer is connected to the positive of the filament.

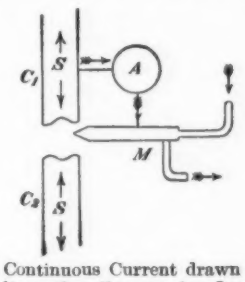



Fig. 5.—A Continuous Current drawn off from an Alternating Current Arc Lamp.

$C_1$, $C_2$. Carbons of the alternating arc. *A.* Continuous current ammeter. *M.* Hollow iron pole kept cold by circulating water. Negative electricity flows through the ammeter from one carbon to the metal pole.

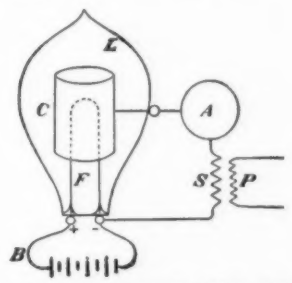



Fig. 6.—Vacuum Valve for Rectifying Electrical Oscillations.

*L.* A glass bulb highly exhausted. *F.* Carbon filament. *B.* Insulated battery. *C.* Cylinder surrounding filament. *A.* Ammeter or galvanometer. *S.* Coil in which secondary oscillations are induced by a primary coil *P*.

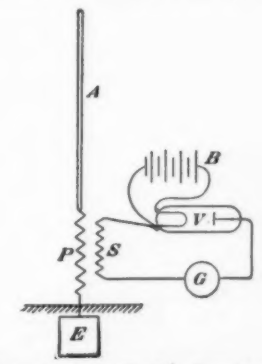



Fig. 7.—Vacuum Valve Used as Receiver in Wireless Telegraphy.

*A.* Aerial wire. *P, S.* Oscillation transformer. *V.* Vacuum valve. *B.* Battery. *G.* Galvanometer.

* Technics.

a very much smaller current, passes. The same experiment can be repeated using platinum loops instead of carbon filaments, and it shows that a high vacuum may be a very good conductor, provided that the negative electrode is rendered incandescent. This shows that the obstruction which a high vacuum offers to the passage of electricity is not due to the mere reduction of the matter in the space (that is, to the rarefaction of the gas), but is, in some way or other, largely dependent upon the temperature of the electrodes; the resistance to the passage of electricity through a vacuum can be rendered very small by intensely heating the negative electrode. Hence, such a bulb containing two carbon filaments forming the two electrodes, one of which can be rendered incandescent, will act as a *vacuum valve*, allowing the electricity to pass in one direction, but not in the other. It permits negative electricity to pass out of the hot electrode, but not out of the cold electrode. If, in place of a single secondary cell (arranged in the shunt circuit, as in Fig. 2, to give a direct current), we employ an alternator, giving an alternating current, but still keep the galvanometer in the circuit, we shall find, as was first shown by the writer in 1889, that a continuous current passes through the galvanometer; in other words, the vacuum posseses a unilateral conductivity, and separates out the two constituents of the alternating current, passing one but not the other. This fact was first demonstrated and described in a paper by the author of this article, presented to the Royal Society in 1889.

In this respect, such a vacuum valve resembles an aluminium-carbon rectifier. It is well known that, if a carbon or iron plate is placed, together with an aluminium plate, in some electrolyte yielding oxygen, then a current of positive electricity can pass from the carbon to the aluminium, but not in the opposite direction. This fact is the basis of some devices for rectifying alternating current, such as a Nodon valve. To return, however, to the vacuum valve. If we take measurements of the current passing through the vacuum when the negative electrode is an incandescent carbon filament and the other a cold metal plate, and, at the same time, measure the difference of potential between the electrodes, we find that the conductivity, as measured by the ratio of current to voltage, is not constant, but varies with the electromotive force. In other words, the resistance of the vacuous space does not follow Ohm's law. As the electromotive force is steadily increased, the current gradually increases up to a certain maximum, and then slightly falls again. The firm line curve in Fig. 3 shows the general relation between current and voltage up to 100 volts; and it will be noticed that the curve is something like a magnetization curve of iron. It follows that the curve of conductivity, represented by the dotted line, is a curve rising rapidly to a maximum, and resembling to some extent the curve of permeability of iron.

For an explanation of these facts we must fall back upon the electronic hypothesis of matter and electricity. According to this view, atoms of matter are built up of electrons, which are point-charges of electricity; and an atom is considered to be made up either of a collocation of positive and negative electrons in orbital motion round one another, or else of negative electrons, or simply of electrons scattered throughout a space, which in some way or other, not yet understood, constitutes a sphere of positive electricity. In any case, facts connected with electrochemistry and radio-activity show that atoms can break up, by giving off electrons, or can part with one or more electrons. Hence, in any mass of matter, such as a metal, there must be, in addition to the complete atoms or molecules constituting the mass, a distribution throughout it of free electrons, the percentage of these increasing with the temperature. These electrons cannot escape from the mass when cold, because if they did they would leave it positively electrified. If, on the other hand, we electrify the mass negatively to a high potential and raise it to a high temperature, electrons can escape freely from it. In every mass of matter there is what we may call a certain "electronic pressure"; hence, it follows that the resistance which a high vacuum offers to the passage of electricity through it is, in fact, the resistance which is offered to the ejection or drawing out of electrons from the surface of the electrodes.

In an interesting paper in the Philosophical Magazine for October, 1904, Lord Kelvin sums up the position as follows: "The labors of many experimenters during the last fifty years, and the comparatively modern atomic theory of electricity, have thoroughly confirmed the view that the space of our best modern vacua, interstellar and interplanetary space, and generally, space occupied only by the luminiferous æther, is a very perfect non-resister of electricity passing through it. Hence, we see that the insulation of electricity in a vacuum is to be explained, not by any resistance of vacant space or of æther, but by a resistance of glass or metal or other solid or liquid against the extraction of electrions* from it, or against the tearing away of electrions or fragments of its own substance."

Lord Kelvin enters into some calculations of a very interesting kind, estimating the force required to extract an electron from the negative electrode. He considers an atom to consist of a sphere of positive electricity (it may be of positive electrons distributed through a spherical space), and he calculates the force necessary to tear a negative electron out of this environment. The force required to displace the negative electron whose charge is $e$ by a distance, $x$, from its position at the center of an atom whose radius is $r$, is equal to $ex/r^3$ electrostatic units. Now, the charge carried by one electron is known to be $3.4 \times 10^{-10}$ electrostatic units, and the radius of an atom is known to be of the order of $10^{-8}$ centimeter. Hence, the force required to make $x/r = 1/9$, or to move an electron from the center of the atom only one-ninth part of the way to the atomic surface, is 320,000 electrostatic units, or equal to 96 million volts per centimeter; and the force required to extract the electron altogether would be equal to 384 million volts per centimeter.

This, as Lord Kelvin shows, means a strain equal to 66.4 tons per square centimeter, and would rupture or pull apart the strongest steel.

It seems, therefore, clearly impossible for any electrostatic force which we can create, to directly break up atoms or draw out electrons from them. On the other hand, it is a cardinal principle in the electronic theory of electricity, that the only way in which an electric current can be produced is by the movement of electrons. Since, therefore, we can produce currents of electricity in conductors by feeble electromotive forces, it follows that free electrons must exist within the metal. We picture to ourselves, therefore, a mass of metal as follows:

It is composed of atoms, each one of which is a complex structure of electrons in motion and vibration. Owing to collisions and mutual reactions, electrons are detached from some atoms, and constitute free point-charges of negative electricity, which remain mixed up with the atoms. The remainder of the atom from which the electron is detached is therefore positively charged, and may be called a positive ion. The free electrons are continually being set free from atoms, and taken up again by others. Hence, at any one moment there is a certain percentage of complete atoms and a certain corresponding percentage of free electrons and positive ions. The equilibrium is dynamic, and no doubt determined by temperature. The free electrons can move about between the atoms and comport themselves like molecules of gas in a vessel. They cannot leave the metal, because, if they did, it would be positively electrified. Hence, any attempt of an electron to remove itself from the conductor is strongly resisted. On the other hand, the electrons diffuse from one place to another in the same mass, if by any reason the concentration of electrons is different at the two places.

Creating an electromotive force in a metallic mass merely means that we make a difference in concentration or density of free electrons between different places, or that the number per cubic centimeter is greater at one place than at the other. Then there is a tendency for electrons to migrate or diffuse from the place where they are most numerous to places where they are less numerous. This diffusion of electrons constitutes an electric current. Electronic movement under variation of concentration follows the same laws as the diffusion of solids in solutions. This law, moreover, when mathematically considered, leads at once to the well-known law of Ohm defining the current under various electromotive forces in a conductor.

Suppose, then, that we seal two platinum wires into the opposite ends of a glass tube, and connect these two wires to a battery, or induction coil, or transformer. These appliances are virtually electron pumps, and force an excess of electrons into one piece of platinum and make a deficit in the other. The one which has an excess of electrons is the negative electrode. If the pressure is great enough, electrons may be projected from the negative electrode. If, however, the electrode is surrounded by air molecules at normal air pressure, the electrons projected from the metal never attain a very high velocity.

Imagine, now, the gas molecules greatly reduced in number—in other words, the air in the bulb rarefied and a "vacuum" made.

We have three broadly marked conditions to consider. We may have the "vacuum" low or high. We may have the electrodes cold or incandescent. We may have the electronic pressure difference, or voltage between them, small or large.

Let us define these conditions more closely. The vacuum is said to be low when the original normal air pressure in it is reduced to one-thousandth of an atmosphere, or it may be only to one three-hundredth. It is said to be high when it is reduced to one hundred-millionth of an atmosphere. The electrodes are said to be cold when not in any way specially heated. They are incandescent when brought to a bright white heat by some external means. The voltage is said to be small when the difference of potential between the electrodes is only a volt or two. It is said to be large when it is some hundreds or thousands of volts.

The phenomena which take place when the "vacuum" is not very high (that is, when the residual gas pressure is only about one-thousandth of an atmosphere), and the electrodes are cold, are very complicated. In this case we have an enormous number of gaseous atoms per cubic centimeter still left, and we have all the beautiful but complex phenomena shown by an ordinary *vacuum tube*, provided the potential difference of the electrodes is made sufficiently great (that is, provided it amounts to some hundreds or thousands of volts). The study of these phenomena has given occupation to a large number of the most distinguished physicists, and it has taken them at least half a century to unravel them. When the vacuum is very high (that is, if the residual gas pressure is something less than one ten-millionth of an atmosphere) the phenomena become simplified. We then observe the well-known effects of the Crookes or Röntgen tube. The electrons in the negative electrodes are projected from it, owing to the great electric force, with very high velocities; and as their path is not sensibly disturbed by the sparsely distributed molecules of the remanent gas, we have all the phosphorescent and other remarkable effects due to the bombardment of these electrodes, and their impact against the glass walls of the vessel or objects placed in the tube. This state makes itself evident by the apple-green phosphorescence of the glass vessel.

We may have a third set of conditions. If the negative electrode is heated to a very high temperature, then even if the electric potential of this electrode is low (that is, if there is only a volt or less difference of potential between the two electrodes) we have a very considerable current of electricity passing across a very highly vacuous space.

This can only be accounted for by the fact that the incandescent carbon or metal which forms the negative electrode is emitting vast numbers of these electrons or point-changes of negative electricity. These are flung out of the heated metal by the high velocities which they attain. Just as it would be possible to impart to a projectile such a velocity as would carry it beyond the earth's attraction, so the electrons present in the metal, when its temperature is high enough, are flung out of the mass; and if that mass is kept at a high potential this torrent of negatively-charged electrons is a current of electricity.

We have in these facts an explanation of many well-known phenomena. One effect in the case of incandescent electric lamps has been much studied by the author; as it was first noticed by Mr. Edison, it is usually called the Edison effect. A plate of platinum or other metal, *P*, is attached to a platinum wire, and this last is sealed into the bulb of an incandescent lamp, *L*. The plate is placed as shown in Fig. 4. If, then, the filament is rendered incandescent by a continuous current, and if we connect a sensitive galvanometer, *G*, between the positive terminal of the filament and the terminal of the plate, we find a current of several milliamperes passing through it. If, however, we connect the galvanometer between the negative terminal and the plate, no current flows. Again, if we render the filament incandescent by an alternating current, we can draw off a continuous current by connecting a galvanometer between the plate terminal and either of the terminals of the filament. These phenomena are susceptible of explanation by the fact that negative electricity (that is, electrons) can escape freely from the hot carbon filament, and hence move across the high vacuum and enter the positively electrified plate. The same thing can be shown with an electric arc. The writer showed many years ago, that if a thin carbon rod (or better still, an iron tube, *M*, closed and made chisel-shaped at one end, and cooled by water led into the interior) is placed with its sharp end just dipping into the electric arc, then a continuous current can be drawn off by a wire connecting this third pole with the positive carbon of the arc, and rendered evident on an ammeter, *A* (see Fig. 5).

On the other hand, no current, or very little current, passes through a wire connecting the negative carbon and this middle pole; or, if the arc is formed with an alternating-current of electricity, in a wire which connects either carbon to a cool middle pole dipping into the arc.

These things are all consequences of the fact that incandescent carbon and metals send out vast numbers of electrons. In other words, an incandescent mass of carbon is flinging negative electricity out of itself. If it is surrounded by air at ordinary pressure the effects of this are not very marked, because the presence of vast numbers of air molecules round the metal keeps the electrons from making their way very far. They must, however, exercise an immense physical effect, and the everyday phenomenon of a coal fire and the combustion of carbon by oxygen is without doubt intimately connected with it. Let us see what account the electronic theory can give of such a familiar fact as the combustion of a piece of coal or carbon.

To begin the combustion, the carbon must be raised to a high temperature. As already explained, this is accompanied by a dissociation of carbon atoms. We have present in the mass of carbon not only complete carbon atoms, but free electrons or point-charges of negative electricity. Therefore there must also be the residues called "carbon positive ions," which are the result of depriving the carbon atom of one or more electrons. The carbon atom is with good reason supposed to be built up of about 12,000 electrons, and of these it can lose four negatives at most. For every four free negative electrons which have escaped, or been flung out from a carbon atom, there will be left one positive carbon ion containing 12,000 or so, *less* four negative electrons. Outside the carbon there are the atoms of oxygen and nitrogen composing the air. Various atoms can, with different degrees of facility, either lose or take up additional electrons. Electrochemical facts indicate that the oxygen atom can acquire or take up two additional negative electrons over and above the 16,000 or so which are its normal constituent number.

Hence, we may consider that, of the electrons projected from the hot carbon, some at least find their way into oxygen atoms, giving them a negative charge of electricity and converting them into negative oxygen ions.

There will, therefore, be a strong electric attraction between the positive carbon ions near the surface of

* Lord Kelvin uses the term *electrion* for an infinitely small point-charge or atom of negative electricity. Most other writers, following the suggestion originally made by Professor Johnstone Stoney, call these point-charges of electricity *electrons*.

the glowing carbon, which have lost four electrons, and the negative oxygen ions hard by, which have each gained two electrons. This electric attraction will be satisfied if two oxygen ions draw near to one carbon ion and form a closely united ionic group, or carbonic dioxide molecule represented by the chemical symbol $CO_2$. These groups being electrically neutral, remove themselves out of the sphere of action, and are the product of combustion of the carbon. As fast as the carbon ions and free electrons are removed from the glowing carbon, fresh ones are formed to keep up the number, and so the process goes on.

The temperature of the burning carbon is kept up by the conversion of potential energy of the oxygen ions and the carbon ions into atomic kinetic energy. The electrons in each ion are set in rapid vibration, and this in turn creates waves in the æther, which are the radiated heat and light. The process is therefore continuous and self-supporting. The combination of the carbon and oxygen ions maintains that temperature which is necessary for the continual production of the electrons in the carbon, and when it is begun at one point in the mass it speedily spreads all over it.

The nitrogen atoms take little part in the process. They do not quite so easily take up electrons as do the oxygen atoms. Hence, they are not in a condition to combine with the carbon ions.

The above process is typical, and proceeds when any metal is heated in air and oxidized or burned. Returning, then, to the vacuum valve, the writer of this article has recently discovered, and announced to the Royal Society, an important property possessed by a high vacuum when the electrodes are at very different temperatures.

A glass bulb contains a carbon filament, such as would be used for an incandescent lamp, and is surrounded by a metal cylinder not touching the filament, the said cylinder being connected to a platinum wire sealed through the glass. Such an arrangement possesses the property that when the filament is rendered incandescent, negative electricity can pass from the hot carbon to the cold cylinder, but not in the opposite direction. This arrangement may act as a vacuum valve if used in the following manner: Let the filament be, for example, a 12-volt carbon filament. It must be rendered incandescent by a small insulated secondary battery, *B*. To the negative terminal of this filament is connected one end of a circuit which includes a sensitive galvanometer, *A*, and the other end of the same circuit is connected to the terminal of the metal cylinder, *C*. This circuit may include the secondary coil of a small transformer or air core induction coil, *S*, *P* (see Fig. 6). If, then, electric oscillations are created in the primary circuit of this transformer by the discharge of a Leyden jar or any other method, these very high frequency alternating currents produce other high frequency currents in the circuit which includes the galvanometer and the high vacuum. Only one of these sets of currents, however, can pass round the circuit, viz., that which is due to a movement of negative electricity from the hot filament to the cold cylinder. The movement of electricity in the opposite direction is prevented, hence the galvanometer gives a deflection and is traversed by a continuous current. This enables us to employ a sensitive mirror galvanometer for detecting electric oscillations.

We may modify the experiment and make use of the apparatus to show many interesting effects. We may, for instance, set up an electric oscillation by the discharge of a condenser in one circuit. This discharge produces, as is well known, a rapid alternating current dying away in intensity; the current flows first in one direction and then in the other, the interval of time between them being exceedingly small, perhaps of the order of a millionth of a second. Then at a distance several feet or several yards away, we may set up another circuit including a galvanometer and a vacuum valve, and we may produce, as above described, a deflection in the galvanometer showing it is traversed by a continuous current when we set up an alternating current in the primary circuit by the discharge of the condenser. We can then show that the high-frequency magnetic field which is producing this effect is entirely arrested by thin sheets of metal; for if we hold a sheet of tinfoil between the primary and secondary coils, the deflection of the galvanometer at once ceases. We can also make use of such an arrangement as a receiver for wireless telegraphy; it is not so sensitive, however, as the coherer or the magnetic detector, but is very useful for many purposes. It would then be used in the following way: Between the aerial wire, *A*, and the earth plate is inserted one circuit, *P*, of an oscillation transformer or induction coil, the other circuit, *S*, including a vacuum valve, *V*, and galvanometer, *G*, as already described (see Fig. 7). If, then, electric waves from a distance fall on the aerial wire, they set up in it rapid electric oscillations, and these induce other oscillations in the circuit of the vacuum valve.

If the vacuum valve has its carbon filament ignited by a small battery, it will permit only one of the constituent currents of the electric oscillation to pass, viz., that for which the movement of negative electricity is from the hot carbon to the cool surrounding cylinder. Hence the galvanometer will give a steady deflection all the time the electric waves are falling on the wire, and if the galvanometer is that type of instrument called a "speaking galvanometer" (or one which responds very quickly to the rise and fall of current through it), it will give deflections larger or smaller in proportion as the wave trains falling upon the aerial are longer or shorter, and in this manner signals in accordance with the Morse alphabet may be transmitted and rendered visible by the deflections of the galvanometer.

A galvanometer of the above kind is used in submarine cable telegraphy, and we can employ precisely the same instrument by the aid of a vacuum valve in connection with wireless telegraphy.

These, then, are some of the practical problems to which we are led by the study of the electric conductivity of a vacuum.

## ENGINEERING NOTES.

**But few of the locomotives** in service to-day, especially in this country, have any part of the cylinder heads, steam chests, cylinders, or other radiating surfaces protected with any kind of non-heat-conducting covering, which should be done to increase the efficiency of the engine, by at least partially protecting these parts from the almost unrestricted drain of mechanical energy through the dissipation of heat.

**The mode of gas-engine regulation** by admission on each cycle enables fly-wheels relatively less heavy to be used. The same may be said of the application of double-acting, and of multiple cylinders. The requirements, however, which are now expected from engines in large electric light stations have given rise to the use of special fly-wheels, with the object of reducing as much as possible the degree of cyclic irregularity. For ordinary industrial purposes a regularity of 1/25 to 1/30 of the speed in one and the same cycle can readily be attained. For electric lighting by continuous-current dynamos it is necessary, with the view of obtaining a steady light, for the degree of irregularity to be less than 1/50 or 1/60, while for the working of alternating-current generators in parallel it should practically be about 1/150.

**Metal arches** are particularly suitable for long spans in certain places. The arch combines the advantages of a graceful appearance with facility of erection without false work. Most of the earlier ones were constructed of cast iron, an important example of which is the Chestnut Street Bridge, in Philadelphia, completed in 1863. The first important steel arch was the St. Louis Bridge, over the Mississippi River, completed in 1874, consisting of three spans, the middle one, of 515 feet, being the largest. The highway bridge across the Mississippi River, at Minneapolis, having two spans of 456 feet each, was completed in 1888. The Washington Bridge, across the Harlem River, New York city, finished in 1889, consists of two spans, each of 510 feet. A number of arches of various types followed, the most noted of which are the two across the Niagara River, one of which, of 550 feet span, carries the tracks of the Grand Trunk Railway and a highway, replacing the Roebling suspension bridge. It was constructed in 1897. The other replaced the Niagara Falls and Clifton Suspension Bridge in 1898. It has a span of 840 feet and is the largest arch of any type in the world.

**There have been** so many improvements and innovations in large and small apparatus entering into steam plants during the last few years, says Engineering Record, that the difference in opinion concerning what is an ideal steam plant is growing wider than it was only five years ago. It is, of course, inevitable that some men will rank certain features of a plant as of greater importance than others. For example, those who consider the appearance of an engine room of importance will look with favor on expensive tile floor and walls, while there are others who will consider the money paid out for this purpose an unnecessary expenditure. Some look wholly at utility. Some weigh the real advantages and disadvantages and estimate the money worth of a plant viewed as an investment, and set up a standard accordingly. The ideal plant in one place will, of course, be far from appropriate in different surroundings, and a standard for one class of service may be unfit for consideration in another class of work. The true ideal, from a strictly engineering point of view, is the attainment of the end in view with the least amount of running expenses and fixed charges. If the design of a steam plant and its later improvements were always made in accordance with an ideal such as this, the results would be highly satisfactory, whereas, in many cases they are quite the reverse. The familiar inquiry, "Does it pay?" is the test that must be applied to a steam plant; if the answer to that question is in the affirmative, the plant is an ideal one for the real purpose of its design.

**If the size of the plant** is sufficient, and the work comparatively steady, the highest possible results may be obtained from compound condensing engines using the highest possible pressure of steam, but under other conditions, such as variable load or low pressure of steam, it may be quite possible that the simple engine will give better results and cost less for repairs. With low steam pressure, non-condensing, there is certainly nothing better or more economical than a single-cylinder Corliss engine where it can be installed to advantage. In the case of direct-driven electric units of small size, it is necessary to use high or medium speed engines, both on account of the loss in friction that would come in if countershaft and belting have to be used and because the higher speed machines will give the best regulation. For small units up to, say, 75 horse-power, or even 100 horse-power, there is nothing better than the modern high-speed automatic engine, provided it is of good design, not overloaded and not overspeeded. A well-designed engine with 12-inch cylinder and 12-inch stroke, which is usually run at 275 to 300 revolutions per minute, and made to develop from 75 horse-power to 80 horse-power, if arranged to run at, say, 225 to 250 revolutions per minute, and to carry 50 horse-power or 60 horse-power, will be as serviceable and give as good results as any type of engine of the same horse-power under ordinary conditions non-condensing, and if the work is variable, requiring quick, close regulation, such as driving electric generators, where the load is irregular, say for supplying current to electric lights and electric elevators, the short-stroke, single-valve type of engine has great advantages.

## SCIENCE NOTES.

**It is of the ocean** more than of any other physical feature of our globe, that our knowledge has increased of late years. Forty years ago we were profoundly ignorant even of its depth, with the exception of a few lines of soundings then recently taken for the first submarine telegraph cables, and consequently we knew nothing of its real vast bulk. As to the life in it and the laws which govern the distribution of such life, we were similarly ignorant, as of many other details. The "Challenger" expedition changed all this, and gave an impetus to oceanographic research which has in the hands of all nations borne much fruit.

**Regarded as a whole** we may say that the initial application of physical knowledge for the purpose of developing our ideas of matter consisted chiefly in the employment of physical methods and instruments in the study of the properties of matter. This stood foremost in physical chemistry in the first period of its existence. Reviewing the history of chemistry, we must acknowledge that one of the first fundamental steps was made by the study of the physical property of weight, and the introduction of a physical instrument, the balance, for this purpose. It was, in large part, on this basis that Lavoisier was the great innovator of chemistry; and it was due solely to the following of chemical change with the balance that chemistry got its fundamental laws of constant weight and of constant and multiple proportions. These were summarized by Dalton in the fruitful though hypothetical conception of atoms, which asserts that every element exists in the form of small unchangeable particles, identical for a given element, but differing with the latter.

**The question** of the importation of preserved meats, other than those cured in the ordinary manner by salting, smoking, or pickling, is a matter of considerable importance. Especially is this true of comminuted meats, which by reason of their fineness of subdivision are not capable of being identified in respect of the animal from which they are derived. Practically all civilized countries now have a system of inspection of animals intended for slaughter, which to a certain extent insures the wholesomeness of the product. The character of the meats, for instance, which enter into a sausage does not appear from an examination of the package itself, and hence such bodies are open to the greatest suspicion. It is deemed advisable in these cases that the exporter should be required to furnish a certificate of inspection by official authority as to the animals from which the meats are derived. This is only reasonable, and it is not believed that such meats should be allowed to enter unaccompanied by a certificate of purity of this kind. The many cases of poisoning from trichinæ and ptomaines, due to the consumption of meats and especially in the case of ptomaines, of preserved meats, should render inspectors extremely careful to be certain that articles of this kind are not deleterious to health. The inspection of sausages and other comminuted meats has given greater cause for concern to the officials in charge of the execution of the law than almost any other kind of food products.

**That great benefits** to mankind have followed the discoveries of recent years is obvious to all, especially with regard to the causes and prevention of yellow fever and malaria. Research is a word heard on all sides; it is the enemy of authority, that tyrannous spirit which has hampered progress and retarded the advance of scientific medicine for centuries. Experimental medicine is responsible for the greatest advances which have been made in our knowledge of the cause, prevention, and cure of disease. Most important discoveries have exerted but a slight direct influence at their inception; their full significance has remained hidden for a time. The majority of such discoveries have been made by those engaged in research in the realms of pure science. Pure science is unselfish; its aim is not profit, yet it is the forerunner of that applied science which is more obtrusively the "servant of man." If we study disease, we must do so for the sake of knowledge; the scientific spirit must enter into our work. The "practical man" may not appreciate such ideals, but he is ever ready to use the discoveries of science for his own ends. All are not born with the instincts of research, but there are many in whom they lie dormant, and it should be the function of educational institutions to detect and foster such men and lead them on to do the work for which they are adapted. But too often from mere lack of means such men drift away into other fields of activity. To carry on research successfully a man needs an assured income. Is it possible that those who are able and willing to help human progress can continue to ignore the devotion and self-sacrifice of such men as Lazear, Myers, Dutton, Plehn, and others who have laid down their lives in the study of tropical medicine? Medical research needs endowment, and it is grievous to see that in this country, where so much is done for charity, so pitiably little is done for the advancement of learning. To teach science as it should be taught in properly equipped and organized institutions is far more expensive in the case of medicine than in that of any

other professional school. It does not suffice to build laboratories; they must also be provided with sufficient funds and equipment to enable them to become working entities.

## TRADE NOTES AND FORMULÆ.

**Tetrachloride of Carbon as an Incombustible Cleaning Preparation.**—Tetrachloride of carbon will dissolve liquid, semi-consistent, and consistent fats, either in a pure state or resinated, as also tar, resins, varnishes, and dyes; and as a cleaning material has the advantage over benzine, that it is absolutely incombustible; it will, however, like benzine, volatilize at ordinary temperatures.

**Putty.**—5 kilogrammes of hydraulic lime, 0.3 kilogramme of tar, 0.3 kilogramme of rosin, 1 kilogramme of horn water (the decoction resulting from boiling horn in water and decanting the latter). The materials are to be mixed and boiled. After cooling, the putty is ready for use. This is an excellent cement for glass, and may be used also for reservoirs and any vessels for holding water, to cement the cracks; also for many other purposes. It will not give way, and is equally good for glass, wood, and metal.—Der Chemisch-Technische Fabrikant.

**"Antizoonine" Composition for Iron Ships.**—80 kilogrammes of colophony, 8 kilogrammes of yellow wax, 36 kilogrammes of copper palmitate, 100 kilogrammes of well-settled linseed oil varnish.

Melt the first three constituents, successively, in the varnish, and let the whole stand six hours, when it is ready for use.

The merit of this preservative compound is that when applied slightly warm it makes, after cooling, an extremely dry outside coating, while the inside layer remains soft. It is for use in painting the lower parts of iron ships, and is a protection against rust and adhering seaweed, as well as against animal growths. It is easily applied, dries in a couple of hours, and makes a very smooth surface, which facilitates speed.

**Cuspidor Powder.**—Peat rubble is ground to a powder, and 100 kilogrammes put into a mixing machine, which can be hermetically sealed. Then are added 15 kilogrammes of blue vitriol, either very finely pulverized or in a saturated aqueous solution. Next are added 2 kilogrammes of formaline, and lastly 1 kilogramme of ground cloves, orange peel, or a sufficient quantity of some volatile oil, to give the desired perfume. The mixing machine is then closed, and kept at work until the constituents are perfectly well mixed; the powder is then ready to be put up for the market. Its purpose is to effect a rapid absorption of the sputum, with simultaneous destruction of any microbes present, and to prevent decomposition and consequent unpleasant odors.—Seifensieder Zeitung.

**Bicycle Cement.**—I. Take 10 parts of gutta percha, 16 parts of India rubber, and 4 parts of isinglass, and let them swell up in 70 parts of sulphide of carbon. The cement thus obtained is to be filled into the cracks (first carefully cleaned and dried) and the parts should be tied together until the cement has hardened. A good rubber cement is also made by dissolving 1 part of powdered shellac in 10 parts of liquid ammonia (specific weight 0.910). The shellac will remain in perfect solution in the ammonia for several weeks. For use, a portion of the gelatinous mass is to be liquefied by gentle heat.

II. Put 1 part of India rubber, cut in narrow strips, to 10 parts of benzine, and set aside, at a temperature of about 30 deg. C., shaking often. There will be no perfect solution, but a thick jelly, which can be thinned to need with benzol. The process can be hastened by heating over a water bath, with a reflex cooler.

III. A rubber cement for bicycles, which comes upon the market in tin tubes, is made of unvulcanized rubber (the so-called "waste" is the cheapest) dissolved in benzine, or also in benzol or sulphide of carbon. It has the consistency of a salve. The solution, in wide-necked, well sealed bottles, takes a day or two.—Pharmaceutische Zeitung, Berlin.

**Paint for Petroleum and Turpentine Oil Reservoirs.**—Sift and mix thoroughly 50 kilogrammes of finely-ground ferroso-ferric oxide (hammer-slag) and 100 kilogrammes of finely-ground Portland cement. Put 32 kilogrammes of this with 10 kilogrammes of very finely-pulverized litharge, and mix thoroughly. Dissolve (cold) 5 kilogrammes of pulverized shellac in 10 kilogrammes of high strength (96 per cent) spirit; also dissolve, cold, 0.3 kilogramme of pulverized gum Arabic in 0.75 kilogramme of glycerine, and add to the shellac solution, stirring well. Stir enough of the freshly-prepared solution into the previously-prepared powder to give the mixture the consistency of paint. Lastly, it is to be put through a color-grinding mill, for thorough mixing. The amount of liquid to be added to the powder depends upon the dryness of the latter.

The material thus prepared is now ready for use, and is to be applied to surfaces after the manner of ordinary paint.

If it is not required that it shall retain its elasticity after application, it is well to mix 5 per cent of very finely powdered glass with the powder before mixing with the liquid.

A coating of this paint upon reservoirs and tanks will entirely prevent the inconveniences resulting from absorption and subsequent exudation of petroleum, as it does not spoil or change, but remains firmly adherent to the material, while sufficiently elastic (as ordinarily compounded, without the powdered glass) to yield to the expansions and contractions of the tanks from changes of temperature.—Der Chemisch-Technische Fabrikant.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## TABLE OF CONTENTS.


PAGE

I. AGRICULTURE.—The Cultivation of the Morel.—By JACQUES BOYER.—2 illustrations ..... 25124

II. BIOLOGY.—Catapiexy, or Feigning Death.—7 illustrations ..... 25123

III. CIVIL ENGINEERING.—Armored Concrete.—II.—By Lieut. HENRY J. JONES.—5 illustrations ..... 25128
Concrete Building Blocks.—By S. B. NEWBERRY ..... 25126
The Rhodesia Railways in South Africa.—By FRANK C. PERKINS.—8 illustrations ..... 25117

IV. ELECTRICITY.—On the Electric Conductivity of a Vacuum.—By J. A. FLEMING.—7 illustrations ..... 25129

V. ENGINEERING.—Engineering Notes ..... 25131

VI. MISCELLANEOUS.—Science Notes ..... 25131
Trade Notes and Formulæ ..... 25132
Unscientific and Scientific Divining Rods.—By GEORGE M. HOPKINS.—7 illustrations ..... 25124

VII. STEAM ENGINEERING.—The Dimensions of the Marine Steam Turbine.—II.—By E. M. SPEAKMAN.—9 illustrations ..... 25130

VIII. TECHNOLOGY.—Factors in Painting Woodwork.—I ..... 25118



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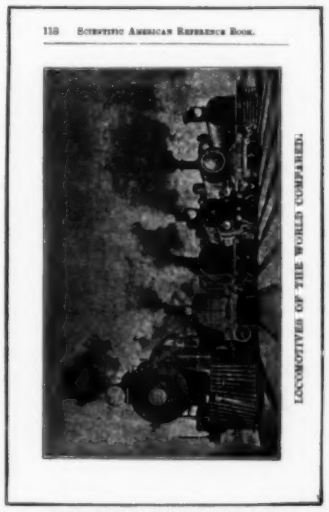


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